Universidade do Minho
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Improving the efficiency of the engineering processes, applying the principles of Lean - Green Thinking in a company of technical foams for the automotive industry

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DECLARAÇÃO DE INTEGRIDADE

Declaro ter atuado com integridade na elaboração do presente trabalho académico e confirmo que não recorri à prática de plágio nem a qualquer forma de utilização indevida ou falsificação de informações ou resultados em nenhuma das etapas conducente à sua elaboração.

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Improving the efficiency of the engineering processes, applying the principles of Lean – Green Thinking in a company of technical foams for the automotive industry

Abstract

This dissertation presents the implementation of Lean - Green principles and their impact on Stokvis Celix to enhance the economic and environmental efficiency of the engineering processes.

Action-Research was employed as the research methodology to identify and address the key issues: high material consumption, limited improvements in production tools, disorganised waste management and accumulation of residues on the production floor. Observations and employee communication were used to identify these problems. Some proposals to solve it were to improve the yield of the production process and implement a recycling system and a container system to collect the equipment residues.

To tackle the issue of high material consumption, the improvement of 42 product tools was suggested to increase their efficiency. The projects yielded total savings of, approximately, 614 352 €, with 592 124 € saved on material consumed, 14 422 € on residues containers and 7 808 € on equipment and labour. These improvements also led to a carbon footprint reduction of 242 166 kg CO_2 eq.

Implementing recycling practices is one of the first steps to ensure sustainability at Stokvis Celix. While finding buyers for direct production scraps proved challenging, opportunities were identified for recycling and valorising indirect residues such as cardboard, plastic film, and plastic bags. There were several purchase proposals for these residues, and the final determination of the most profitable proposal will depend on the effectiveness of Stokvis' storage practices.

Introducing a residues container system on the equipment has positively impacted the production process, ensuring the safety of equipment workers and avoiding the residues accumulation on the floor. This system has significantly reduced cleaning time from 33 to 20 seconds, minimised equipment stoppages, and enhanced working conditions. Moreover, it has proven cost-effective by optimising resource utilisation and reducing costs per stop from 0.12 to 0.17€, depending on the number of workers.

Overall, Stokvis Celix can successfully reduce material waste, increased yield, and achieve significant cost savings with the suggestions proposed. These improvements can contribute to the company's economic sustainability but were also aligned with environmental responsibility. By implementing Lean - Green principles and continuously seeking opportunities for improvement, Stokvis Celix can position itself as a more efficient, cost-effective, and environmentally conscious organisation in the industry.

KEY-WORDS: Lean - Green, Material Efficiency, Sustainability, Residues

Melhoria da eficiência dos processos de engenharia, aplicando os princípios Lean - Green Thinking, numa empresa de espumas técnicas para a indústria automóvel.

RESUMO

Esta dissertação apresenta a implementação dos princípios Lean-Green e o seu impacto na empresa Stokvis Celix, de modo a melhorar a eficiência económica e ambiental dos seus processos de engenharia. A metodologia de investigação utilizada foi a *Action-Research*, onde foram identificados os seguintes problemas: elevado consumo de material, melhorias limitadas nas ferramentas produtivas, gestão de resíduos desorganizada e a acumulação de resíduos no chão. Estas situações foram identificadas através de observação e comunicação com os funcionários. Algumas das propostas realizadas incluem o melhoramento do rendimento das ferramentas produtivas, implementação de um sistema de reciclagem e um sistema de contentores para recolher os resíduos nas máquinas.

De modo a ultrapassar o elevado consumo de material, foram sugeridas a alteração de 42 ferramentas produtivas de modo a melhorar a sua eficiência. As sugestões proporcionam poupanças de aproximadamente 614 352 €, sendo 592 124 € relativos a material consumido, 14 422 € a contentores de resíduos e 7 808 € a custo de equipamentos e mão-de-obra. Estas melhorias também resultam numa redução da pegada de carbono de 242 166 kg CO_2 eq.

A implementação de práticas de reciclagem é um dos primeiros passos para a sustentabilidade da empresa. Embora seja desafiante encontrar interessados nos resíduos diretos da produção, como espumas, borrachas e fitas adesivas, foram identificadas oportunidades para reciclar e valorizar os resíduos indiretos, como cartão, filme e sacos de plástico. Houve várias propostas de compra destes, sendo que a proposta mais lucrativa dependerá da eficácia das práticas de armazenamento da Stokvis.

A introdução de um sistema de contentores para a recolha dos resíduos diretamente das máquinas teve um impacto positivo no processo de produção, garantindo a segurança dos trabalhadores das máquinas e evitando a acumulação dos resíduos no chão. Este sistema reduziu o tempo de limpeza de 33 para 20 segundos, minimizou as paragens das máquinas e melhorou as condições de trabalho. A utilização dos contentores reduziu o custo por paragem entre 0.12 a 0.17 €, dependendo do número de trabalhadores.

Em suma, a Stokvis Celix através das medidas sugeridas poderá reduzir o desperdício de material, aumentar o rendimento e atingir poupanças significativas. Estas melhorias contribuem para a sustentabilidade económica e ambiental da empresa. Ao implementar os princípios Lean - Green e procurar continuamente oportunidades de melhoria, a Stokvis Celix posiciona-se como uma organização mais eficiente, rentável e consciente do meio ambiente.

PALAVRAS-CHAVE: Eficiência Do Material, Lean - Green, Sustentabilidade, Resíduos

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List of abbreviations and acronyms

3BL – Triple bottom line

BSC – Balance Scorecard

CE – Circular economy

CFP – Carbon Footprint

CNC - Computer Numerical Control

DEFRA – Department for Environment, Food & Rural Affairs

EMAS – Eco-Management and Audit Scheme

EOP – End of the Project

ETO – Engineer-To-Oder

EU – European Union

GHG – Greenhouse Gas

ISO – International Organization for Standardisation

JIT – Just-in-time

LCA – Life Cycle Assessment

ME – Material Efficiency

OECD – Organization for Economic Cooperation and Development

SDGs – Sustainable Development Goals

SOP – Start of the Project

TPS – Toyota Production System

WBSCD – World Business Council for Sustainable Development

Y – Yield

1. INTRODUCTION

This dissertation is related to a research project conducted at Stokvis Celix Portugal's facilities. The project's primary goal was to improve, through Lean - Green methodologies, the company's economic and environmental efficiency of the engineering processes. This chapter introduces the background, motivation, and primary and specific objectives. Next, the research methodology framework is explained, followed by an overview of the dissertation's organisation and structure.

1.1 Background and Motivation

In a world where competitiveness is the keyword for the survival of many companies, there is a growing interest in selecting the most appropriate competitive strategy to overcome competitors. Furthermore, they are also under pressure to act on the biggest problems of the 21^{st} century, which include climate change, fuel consumption and the rising cost of energy and resources (Hallam et al., 2018).

The combination of the mentioned problems encourages the search for strategies to increase profit and be an organisation with environmental and social responsibility (Cherrafi et al., 2016). Some companies try to achieve that by developing proactive attitudes and strategies towards more sustainable operations through eco-efficient production systems and compensation mechanisms (Abreu et al., 2016). Such process may go through the adoption of organisational methodologies that promote ideas of "doing more with less", as endorsed by Lean Production (Womack & Jones, 1996) and of "creating more with less", as encouraged in the concept of eco-efficiency (BCSD, 1993). The synergies among those strategies are plenty and unequivocal, which has resulted in an approach known as Lean–Green. This link associates a value with efficiency in operational and environmental terms (Florida, 1996).

On the one hand, companies seek philosophies, methods, and tools to improve their value chain to meet customer requirements (Hallam et al., 2018). The already mentioned Lean Production was one of the most popular, emerged after World War II. Toyota Motor Company developed this production philosophy during an economic crisis when mass production was not viable due to the lack of capital and foreign currency. Lean Production advocates for eliminating waste within an organisation through improvement actions. Waste refers to anything that does not directly contribute to adding value to a product from the perspective of the customer's needs and requirements. Seven main waste classes have been identified: overproduction, waiting, transport, over-processing, inventory, movements, and defects (Monden, 2012; Ohno, 1988). This philosophy has been popularised through the book "The Machine That Changed the

World” by Womack, Jones, and Roos. The application of Lean Production increases the production system's capacity and improves the value chain to meet customer requirements (Womack et al., 1990).

On the other hand, eco-efficiency is a concept that has gained increasing attention in recent years due to its potential to reduce environmental impacts while improving economic performance. It is the idea of creating more value with less environmental impact. It can be achieved by implementing sustainable practices in all the product or service life cycle stages, from raw material extraction to disposal (Passetti & Tenucci, 2016).

Lean production and eco-efficiency are concepts with different approaches: reducing waste (Lean) and environmental impact (Green). However, now, more than ever, these two approaches should be hand in hand.

This dissertation was conducted in an industrial environment at Stokvis Celix, Portugal. This company specialises in converting flexible foamed plastics and rubbers into various formats, with the ability to include adhesives for different applications, mainly automotive, per customer demands. As such, the company handles the design, engineering, and production process from start to finish, and each order is unique. This approach is known as Engineer-To-Order (ETO), which necessitates significant effort in sales, purchasing, engineering and production (Strandhagen et al., 2018). In addition, the company produces a wide range of models for each product with limited production volume and implementing Lean–Green strategies presents a significant challenge.

1.2 Objectives

The main objective of this dissertation was to increase the economic and environmental efficiency of the engineering processes of Stokvis Celix through the application of Lean–Green tools. For the achievement of the objective mentioned above, it was required to:

- Identify and characterise Lean wastes in production;
- Identify and characterise the residues;
- Identify the product references where the yield could be improved;
- Calculate the monetary savings;
- Calculate the environmental balance of the implemented measures;

- Standardise the implemented measures.

The accomplishments of such objectives allowed to:

- Reduce waste;
- Increase material efficiency;
- Increase productivity
- Reduce costs.

1.3 Research Methodology

The present dissertation had a duration of 6 months, and it was used the Action – Research method.

Action – Research is a methodology that combines research and action to address practical problems in real-world contexts. It is characterised by its collaborative and participatory nature, involving stakeholders in identifying and implementing solutions. This methodology combines research and action, promoting reflective practices, continuous learning, and transformative outcomes. By engaging in a cyclical process of planning, acting, observing, and reflecting, action research enables stakeholders to actively participate in shaping their environments and generating knowledge that is contextually relevant and applicable (Stringer, 2007). Figure 1 presents a detailed Action – Research model.

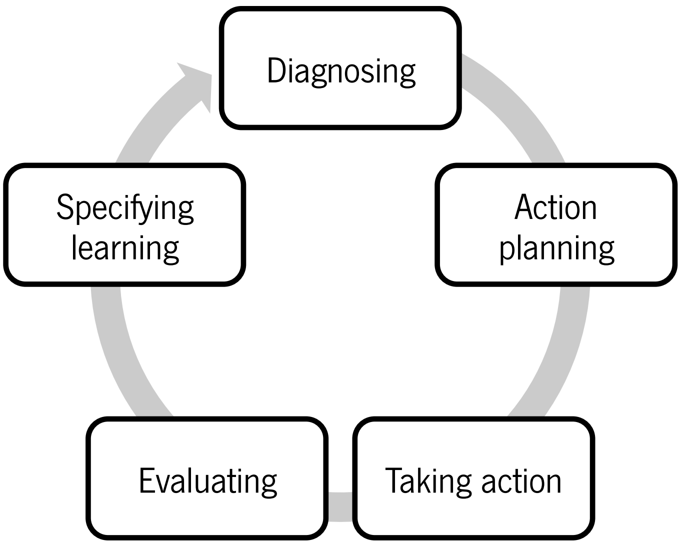


Figure 1 - Detailed Action Research Model
(adapted from Susman & Evered, 1978)

The process of methodology Action – Research consists of five main steps.

Firstly, the problem diagnosis stage entails identifying areas for improvement or specific problems. It involves evaluating and gathering pertinent data, such as identifying material inefficiencies in products and assessing employee safety risks.

Secondly, an action plan is developed, including setting objectives, conducting research, and selecting appropriate methods. This stage involved thoroughly analysing various product tools, contacting multiple recycling companies, and studying container configurations.

Next, the implementation phase required designing and executing the solution to address the identified problems. It encompasses testing, adapting, and refining the strategies outlined. For instance, several tools were tested, and the containers underwent testing in the equipment.

The fourth step involved evaluating the effectiveness of the implemented solutions. This stage consisted of analysing the economic and environmental impacts resulting from the proposed measures.

Lastly, it was necessary to reflect on the results achieved and future actions that should be taken to improve it if necessary.

1.4 Dissertation structure

This dissertation is divided into seven chapters. During the first chapter, a brief framework of the project that served as the basis for this dissertation was carried out, the main objectives to be achieved were defined, and the research methodology that was used for this purpose.

In the following chapter, a bibliographic review was carried out on the main concepts relevant to this project's context.

The third chapter begins with a brief presentation of the organisation where this dissertation was carried out, dealing with the history of the Stokvis Celix, its products, its customers, and its production process.

In the fourth chapter, a detailed description of the area under study and a critical analysis of the organisation's current situation was carried out.

The fifth chapter describes the various proposals for improvement developed for the problems identified in the previous section.

The sixth chapter details the expected results by implementing the improvement actions presented and assessing their impact.

Finally, in the seventh and final chapter, the main conclusions obtained are described as well as some proposals for future work.

2 Literature review

This chapter intends to present the literature review for this dissertation to provide an overview of the main concepts, such as Lean production, Engineer-To-Order, Sustainability, Eco-efficiency and Lean–Green.

2.1 Lean Production

According to Womack et al. (1990), Lean Production is an organisational production model that aims to eliminate waste, create value, satisfy the customer's needs and make continuous improvements. The goal consists of "doing more with less", which means producing more with fewer resources through the continuous elimination of waste (Womack et al., 1990).

Its popularisation occurred with the release of the book "The Machine That Changed The World" by James P. Womack, Daniel T. Jones and Daniel Roos in 1990, which describes the Toyota Production System. The authors studied the practices of Japanese automakers, particularly Toyota, and highlighted the principles that enabled them to achieve higher productivity, improved quality, and reduced waste compared to their Western counterparts, such as Europe and the United States of America (Womack et al., 1990).

For Liker (2004), Lean Production is defined as a business philosophy that seeks to involve all people in the organisation in eliminating waste and creating value based on a proactive culture of constant improvement (Jeffrey K. Liker, 2004).

Another example is the definition of Kerper (2006), who defines Lean Production as a systematic approach to identifying and eliminating waste through continuous improvement, directing the product and production processes to customer requirements (Kerper, 2006).

2.1.1 Origin

Lean Production is a philosophy that originated in Japan in the 1950s when Toyota developed a new approach to manufacturing that focused on minimising waste and maximising efficiency. During this period, Japan was recovering from World War II. Consequently of this war, the country was facing severe resource constraints, which forced companies to innovate ways of producing products with limited resources (Womack & Jones, 1996).

One of the key figures in the development of Lean Production was Taiichi Ohno. He had the task of improving Toyota's manufacturing processes. Ohno concluded that traditional mass production was inefficient, with excessive waste, which made it difficult for companies to compete in the global market. So, Ohno developed the Toyota Production System (TPS), the foundation of Lean Production (Ohno, 1988). Fujio Cho, an Ohno's discipline, summarised into a house diagram, which represents all the developed methods in a structured way (Figure 2).

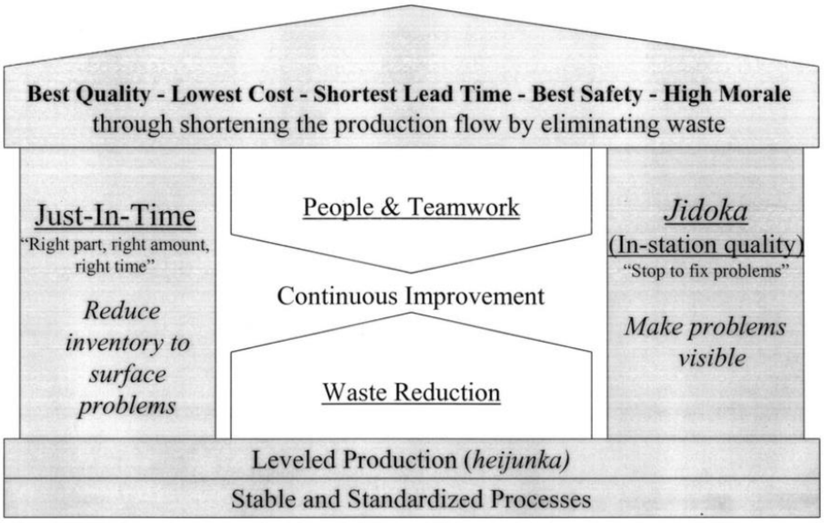


Figure 2 - TPS House
(Liker & Morgan, 2006)

TPS aims to achieve the best quality at the lowest cost with short lead times while prioritising safety. The foundation of TPS is built upon stable and standardised processes and levelled production through heijunka, ensuring stability and creating opportunities for improvement. The pillars of TPS are Just-In-Time (JIT) production and jidoka. JIT means that materials and components are only delivered to the production line when needed, reducing the need for extensive inventories and storage space. This principle helps companies reduce costs and increase efficiency by producing only what they need when needed. Jidoka refers to a "machine with human intelligence", where the intelligence is applied to stop the process when the defect occurs, making it impossible to go through production (Liker & Morgan, 2006).

TPS also emphasised involving everyone in the continuous improvement process, not solely technical experts. Continuous improvement is the heart of TPS, ensuring that every aspect of the process is engaged in ongoing improvement efforts. This process constantly evaluates and refines processes to eliminate waste and improve efficiency (Liker & Morgan, 2006). Companies can achieve significant improvements in the future by making incremental improvements to the production process. This principle is, in Japanese, known as “Kaizen”, which means “change for the better” (Shingo, 1988).

So, Lean is a world-leading production strategy that has proved its worth in an industrial environment. It emphasises the importance of the customer’s value by focusing on delivering value to the customer. As a result, companies ensure that they meet their needs and expectations, increasing their loyalty and business success (Moreira et al., 2010).

The National Institute of Standards and Technology (NIST, 2010) defends that Lean Production is “a series of tools and techniques for managing your organisation’s processes. Specifically, Lean focuses on eliminating all non-value-added activities and waste from processes. Although Lean tools differ from application to application, the goal is always an incremental and breakthrough improvement. Lean projects might focus on eliminating or reducing anything a final customer would not want to pay for scrap, rework, inspection, inventory, queuing or wait time, transportation of materials or products, redundant motion and other non-value added process steps.” (NIST, 2010).

2.1.2 Waste Types

The Lean Production philosophy has gained prominence in the manufacturing industry due to its effectiveness in waste reduction strategies. It identifies three types of waste: Muda, Mura, and Muri. These are essential to promote production process improvement.

Muda is the primary focus of Lean Production. It represents the activities or processes that consume resources, adding time and costs, but do not create value for the client, so it aims to eliminate non-value-adding activities (Womack & Jones, 1996). According to Shah et al. (2018), Muda is one of the primary goals of Lean Production, as it reduces costs, increases productivity and improves customer satisfaction (Shah et al., 2018). Value is everything the client is willing to pay for a product. However, according to Lean Enterprise Research Center, in the productive processes, only 5 % of the activities add value, 35 % are activities that do not have value but are needed, and 60 % are not necessary and do not add any value (Melton, 2005). Taiichi Ohno identified the original seven types of Muda wastes. These include (Ohno, 1988):

- <u>Overproduction</u>: It produces more than demand or before it is needed, resulting in excess inventory, storage costs and potential obsolescence. This uses larger raw materials consumption and labour use, consequently, more tied capital and more handling and movement of materials.

This type of waste is considered the worst due to its implications, leading to resource overload and excessive inventory. If companies overproduce, they will purchase more raw materials to produce more products. This implies more consumption of energy, water, and other inputs, as well as the allocation of more human resources. Simultaneously, more waste will be produced. Therefore, overproduction will impact earth resources by exploring more than necessary;

- Over-processing: Performing unnecessary activities, such as over-processing, over-engineering or over-designing, which adds cost but no value;
- Waiting: The time spent on materials, equipment, instruction, or approvals management leads to idle workers and increased lead times.
- Transportation: Time wastes result due to materials, products, or equipment unnecessarily moving, which increases the risk of damage or loss.
- Motion: This waste consists of unnecessary movement by the workers, resulting in fatigue, injury, and decreased efficiency.
- Inventory: Excess inventory that ties up capital, storage space and resources and can lead to waste and obsolescence
- Defects: Producing defective products, which can result in rework, scrap and customer dissatisfaction

In addition to these seven types of Muda wastes, some researchers add an eighth type of Muda, which is the underutilisation of people's skills and abilities, that is, disregarding workers' ideas and proposals or not using the skills to promote improvements (Liker, 2004).

The second type of waste is Mura, which consists of variations or inconsistencies in the production process. It results from a lack of standardisation, poor planning, or inadequate process. Inconsistent production can lead to variations in product quality, increasing the risks of defects or errors, which can affect customer satisfaction. Standardisation and process control are essential to reducing Mura and ensuring consistency and quality manufacturing (Liker & Hoseus, 2008).

The third type of waste is Muri, which refers to overburdening resources or employees. Muri can result from excessive workloads, poor planning, or inadequate training. According to Womack & Jones (2003), Muri can reduce productivity and increase stress, errors and employee burnout (Womack & Jones, 2003).

2.1.3 Lean Thinking Principles

Lean Thinking advocates a management style that emphasises teamwork and engagement in the organisation (Womack & Jones, 1996). Furthermore, it encourages and motivates employees to look for problems, think about and solve them, leading to continuous improvement (Alves et al., 2012). Five principles of Lean Thinking guide this philosophy, as outlined below (Womack & Jones, 1996):

1. Value: It is necessary to define value from the customer's perspective. This is understanding what the customer wants and needs and designing the products according to those. Therefore, companies must focus on delivering value to the customer rather than simply maximising the output.

2. Value Stream: This principle aims to create a map of the value stream, a series of steps required to deliver a product. This involves identifying all the steps in the process, including those that add value and those that do not. Once the value stream is mapped, companies can identify areas where waste can be eliminated and add value.

3. Flow: By creating a flow, it is possible to eliminate obstacles and delays in the value stream. By creating flow, companies can improve efficiency, reduce lead times, and increase responsiveness to customer demand.

4. Pull: Establishing a pull means producing the products only when needed. This helps reduce the inventory and improve responsiveness to customer demand.

5. Perfection: The fifth principle of Lean Thinking is to pursue perfection, continuously improving processes and products to eliminate waste and create more value for customers. This involves a culture of continuous improvement, with a focus on problem-solving and waste reduction. In addition, companies must be willing to engage all employees in the process, encouraging them to identify areas for improvement to take ownership of the solutions.

Implementing these principles requires a fundamental shift in the way a company operates. The principles of Lean Thinking offer a roadmap for creating customer value while minimising waste. Companies can improve efficiency, reduce costs, and increase customer satisfaction by focusing on value and waste reduction. It can also lead to a more engaged and empowered workforce, as employees are encouraged to improve processes and products actively.

For Lean Thinking to be implemented in a company, a structured approach and the principles of value, waste, and flow must be rigorously applied throughout the supply chain (Melton, 2005).

2.1.4 Lean Tools

Lean Production is a set of management techniques focused on eliminating waste and creating value. A key component of Lean Production is using Lean tools to identify and eliminate waste in all aspects of the manufacturing process. The tools used in this dissertation were Kaizen, 5S and Standard Work.

2.1.4.1 Kaizen

Imai introduced the term Kaizen in 1986, which defines it as "ongoing improvement involving everyone – top management, managers and workers". It is an overarching concept encompassing various Japanese business practices that gained global recognition, such as Kambam, JIT, zero defects and Total Quality Management (Imai, 1986).

Kaizen focuses on making small, incremental improvements to processes and systems to improve efficiency, quality, and productivity over time. So, it is based on the idea that every process can be improved. The Kaizen process usually involves the following steps (Imai, 1986):

1. Identify the problem or the opportunity.
2. Analyse the current process and identify the root cause of the problem.
3. Develop and test potential solutions.
4. Implement the best solution.
5. Evaluate the results and make further improvements as necessary.

The Kaizen process is iterative and ongoing, with each cycle of improvement building on the previous one. Over time, these small improvements can add to significant gains in efficiency, quality, and productivity (Womack & Jones, 1996).

2.1.4.2 5S

5S technique was introduced at the end of the 1960s in Japan, while Osada (1991) and Hirano (1995) proposed the principal framework of its application.

According to Hirano (1995), the 5S technique is a systematic approach to achieving cleanliness and standardisation of workplaces. This technique consists of five steps designed to improve efficiency and provide continuous improvement in all sectors. The designations of the five stages start with the letter "S" when written in Japanese, and there are (Hirano, 1995):

1. *Seiri* (Separate): This is to remove unnecessary elements. The workspace must only have the essentials to perform the activities.

2. *Seiton* (Organize): It refers to having proper local to stowage the materials to be easy to locate and store.

3. *Seizo* (Clean): The workplace and equipment must be clean to reduce the risk of accidents, improve product quality, and promote a favourable work environment for employees.

4. *Seiketsu* (Standardization): To support the 3S previously described, it is necessary to establish standards/procedures, and they should become part of the organisational culture.

5. *Shitsuke* (Discipline): To fulfil the 5S technique, it is necessary to guarantee that the 4S mentioned becomes included in the employees' routine. To ensure the sustainability of the 5S methodology, audits are carried out.

According to the magazine 'The Fabricator', US companies improve the 5S methodology to 6S. They added a new S to the 5S technique, which refers to safety that includes safe behaviour and observation (Randhawa & Ahuja, 2017).

2.1.4.3 Standard Work

The source of modern standardisation was the principles of industrial engineering presented by Frederick Taylor, the "father of scientific management". The traditional standardisation method prohibits the possibility of improvement. It considers achieving the standards the main goal as if they are the ultimate and optimum level of performance. On the other hand, the Lean method views standardisation as the basis for improvement, and the standards are expected to continuously develop (Liker & Meier, 2006; Liker, 2004).

Henry Ford's perspective influenced Toyota's view of standardisation: the standardisation process is the basis for future improvement. Therefore, standards should not have limits but be the best way of performing at present, which is to be improved in the future (Liker, 2004).

In any system, the 4 M's (ManPower, Machine, Material and Method) are used to meet customer expectations. The outputs, products, or services should meet the productivity, quality, cost, delivery time, safety and morale requirements. The standardisation method is a mix of Man/Woman, Machine and Materials, improving the process. The method tells the workers what to do, when and in what sequence (Dennis, 2007).

The Lean methodology reduces waste from inconsistency and randomness in processes and activities. Achieving waste reduction requires minimising process variation and implementing standardised work procedures, which can be visually controlled. Furthermore, by creating a baseline for detecting abnormalities, quick adjustments can be made to ensure consistent performance (Liker & Meier, 2006).

For continuous process improvement, the production processes should be standardised and stabilise. Otherwise, any attempts to improve will only add more variation to the process (Liker, 2004)

Standardisation is very beneficial to organisations but is very hard to implement and to maintain. Therefore, effectively implementing standardisation is essential for good management support and communication with the workers.

According to Liker (2004), Lean standardised work comprises three elements:

1. Takt Time: The required time to finish a job at the pace of the client's requirement.

2. Sequence of processes

3. Stock on hand: the needed inventory for the worker to complete the standardised work.

2.1.5 Engineer-to-order and the Lean Production application

Engineer-To-Order (ETO) is a manufacturing process in which products are designed and built to customer specifications. This process differs from Make-to-Stock and Make-To-Order processes, which involve producing standardised products or customising existing products to meet customer needs (Schulze & Dallasega, 2023). ETO requires higher engineering expertise, customisation, and flexibility, making it a complex and challenging manufacturing process (Strandhagen et al., 2018).

The ETO process usually starts with a customer inquiry, in which the customer provides detailed specifications for the product they need. The manufacturer then designs and engineers the product, working closely with the customer to ensure it meets their needs and expectations. This process involves high collaboration and communication between the manufacturer and the customer (Strandhagen et al., 2018).

One of the main advantages of ETO is that it allows for greater customisation and flexibility than other manufacturing processes. Each product is designed to meet the customer's specifications and needs (Strandhagen et al., 2018). However, ETO also presents several challenges for manufacturers. One of the biggest challenges is the complexity of the engineering and design process. Since each product is custom designed, it requires high engineering expertise and resources to meet the customer's specifications. This can lead to longer lead times and higher costs, making ETO less profitable than other manufacturing processes. Another challenge of ETO is the need for close collaboration and communication with customers. Again, since each product is custom-designed, manufacturers must work closely with customers to ensure the final product meets their needs and expectations. This requires a high level of customer service and communication skills and the ability to manage customer expectations and address any issues or concerns that may arise (Schulze & Dallasega, 2023).

Several tools and methodologies can support ETO manufacturing, including Computer-Aided Design (CAD) software, Finite Element Analysis (FEA) tools, and Lean Six Sigma methodologies. These tools can help streamline the design and engineering process, reduce waste, improve efficiency, and ensure that the final product meets the customer's requirements (Korhonen, 2020).

Production performance can be hindered by three primary enemies: variation, complexity and weak leadership (Hilletofth, 2009; Lampel & Mintzberg, 1996). While Lean Production has historically reduced variability by standardising products and processes, ETO's main point is creating products tailored to customers' needs. However, customisation introduces variety into the production system and, if not appropriately managed, can lead to increased variation (Powell & Stoel, 2017). So, dysfunctional variability should be reduced, but variety is necessary to keep customisation. Variety and variation are two concepts that can be confusing. The term variety refers to using different components, parts, or assemblies to give other functionalities to the same product. In contrast, variation refers to the differences in product development to meet customer demand. Introducing variety into a process can increase variation, which is considered an enemy of production performance. However, in ETO, variety is necessary to personalise the process for each customer. On the other hand, too much variety can result in increased variation, reducing performance and increasing costs (Within et al., 2020).

2.1.6 Balance ScoreCard and Lean Thinking

The Balanced Scorecard (BSC), as pointed out by Kaplan & Norton (1992), is a tool used to assess and enhance the performance of businesses (Kaplan & Norton, 1992). Four perspectives make up the BSC training (Kaplan, 2001):

1. Financial: Relates to economic performance and viability;
2. Customer perspective: Helps to identify the current and future market segments and customers and to assess the performance regarding aspects such as time, quality, service, and cost of offerings;
3. Internal business process perspective: Refers to the efficiency and quality of the processes;
4. Innovation and learning perspective: Concerns innovation and improvement possibilities regarding infrastructure, technology, culture, and human capital.

The BSC, as defended by Kaplan & Norton (1992), eliminates information overload and concentrates executives on a small number of crucial metrics by reducing the number of measures employed (Kaplan & Norton, 1992).

Integrating Lean Thinking and the BSC provides a powerful framework for measuring and improving company performance. With its four perspectives, the BSC aligns strategic goals and performance measures across the organization. Lean principles, on the other hand, emphasize value creation, waste reduction, and continuous improvement. The financial perspective of the BSC aligns with Lean's focus on shareholder value. The internal process perspective of the BSC correlates with Lean's emphasis on process optimization and waste elimination. Innovation and Learning are vital aspects that Lean Thinking and the BSC address. They recognize the importance of creating a learning organization that constantly adapts and improves (Stevanović & Čečević, 2018).

By integrating Lean principles into the BSC, organizations can measure and manage performance holistically, optimize processes, deliver customer value, and foster a culture of learning and growth. This integration enhances overall organizational effectiveness and ensures alignment with strategic objectives in a dynamic and competitive business environment (Stevanović & Čečević, 2018).

2.2 Sustainability

This section presents sustainability presentation and origin, followed by the sustainability goals and sustainable industry certifications. Lastly, some sustainability tools.

2.2.1 Concept origin

Sustainability has become a crucial concept in recent years as the world struggles with environmental degradation, depletion of natural resources and climate change, which significantly impact the planet and biodiversity.

In 1987, in the publication of "Our Common Future", United Nations defined sustainable development as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This concept is still widely used to define the modern concept of sustainability (UN WCED, 1987). Pappas (2012) expanded the WCED definition and defined sustainable society as "a society possessing the ability to continue to survive and prosper, not just concerning environmental resources and economic development, but also concerning the quality of life as it pertains to conditions that promote sustainable human activity and growth (...). A sustainable society meets these needs simultaneously and in the context of human respect and the ability to negotiate differences without violence". For the author, sustainability is not restricted to treating environmental resources and waste (Pappas, 2012).

2.2.2 Sustainability development goals

The business and industrial sectors have focused on the "triple bottom line" (3BL) concept, which encompasses economic, environmental, and social sustainability (Figure 3).

Figure 3 - Triple Bottom Line

This approach was developed by Elkington (1998). It aims to balance these three pillars of sustainability from a microeconomic perspective. The 3BL recognises that all three pillars are equally essential for sustainable business practices. Companies must strive for economic growth while maintaining their integrity. They must also be conscious of their environmental impact and seek to reduce it throughout their product lifecycle. In addition, companies must respect human rights, promote equity, and make social investments to ensure social sustainability (Elkington, 1998).

Sustainable development meets environmental and social challenges due to growing populations and rising consumption. So, in 2015, United Nations General Assembly developed the 17 Sustainable Development Goals (SDGs) as a blueprint for achieving a more sustainable future by 2030. They cover a range of areas, including poverty, education, health, gender equality, clean water and sanitation, sustainable cities, climate action, and more. The 17 SDGs, represented in Figure 4, provide a comprehensive framework for promoting sustainable development. Governments, businesses, civil society organisations, and individuals worldwide have widely embraced them (United Nations, 2015). However, achieving these goals requires collective action and commitment from all stakeholders, and progress has been uneven.

Figure 4 - The 17 Sustainable Development Goals (SDGs)
(United Nations, 2020)

The recent rapid industrialisation in developing countries has produced severe environmental impacts, and therefore the concept of sustainable industrialisation has been increasingly promoted (Halkos & Gkampoura, 2021). As the world population grows and demand for goods and services increases, industry's impact on the environment becomes more significant, contributing to environmental degradation. They consume massive resources and produce a large quantity of waste and pollutants. The production and disposal of products also contribute significantly to the depletion of natural resources and waste production. Based on UNSF data, the world's material footprint in 2017 was 85,9 billion metric tons, while in 2010 was 73,2 billion metric tons (United Nations, 2020). Therefore, it is essential to promote sustainability in the industry to ensure that economic growth does not come at the expense of the environment. Many companies have realised the importance of sustainability as a factor for success. Its development has been defined as the balance of economic success, ecological protection and social responsibility (Uhlman & Saling, 2010). So, a sustainable industry plays a critical role in achieving the SDGs. Moreover, this sector can contribute to the achievement of several SDGs:

- Goal 7: Affordable and Clean Energy
- Goal 8: Decent Work and Economic Growth
- Goal 9: Industry, Innovation, and Infrastructure Goal Renewable energy in the industry can contribute to Goal 7 by reducing greenhouse gas emissions.
- Goal 11: Sustainable Cities and Communities

- Goal 12: Responsible Consumption and Production. For example, the use of and promoting sustainable energy production. Industry can also contribute to Goal 12 by implementing circular economy principles, reducing waste, and promoting responsible resource use.

Therefore, promoting sustainability in the industry is crucial to achieving the SDGs. A sustainable industry can be achieved through the growth of innovation, the use of sustainable materials, sustainable design, renewable energy sources, circular economy principles, and the development of sustainable supply chains.

2.2.3 Environmental Management Systems and Sustainability Certifications

Environmental sustainability has become a key priority for companies, academic institutions, and policymakers. As a result, several environmental management systems and sustainability certifications have been created to control companies' environmental impact and spread of green practices, for example, ISO 14001, Eco-Management and Audit Scheme (EMAS), Carbon Trust Standard, Forest Stewardship Council (FSC) and Monitoring Certification Scheme (MCERTS) (Sartor et al., 2019).

ISO 14001 and the EMAS are the most common management system certifications, which define and formalise responsibilities and activities regarding environmental management processes. Their acquisition generates information for planning, control, and external reporting activities. Empirical studies show that ISO 14001 and EMAS encourage technical and organisational innovations and positively influence environmental performance and, under some circumstances, also economic performance (Passetti & Tenucci, 2016).

ISO 14001, issued by the International Organization for Standardisation (ISO) in 1996, is today's most popular environmental certification (Sartor et al., 2019). The ISO 14001 standard does not foresee the establishment of precise indicators, but it requires organisations to supervise and measure their environmental performance regularly. Therefore, one might assume that ISO 14001 certification tends to encourage the consideration of different indicators, such as the use of energy and water, atmospheric emissions and regulatory compliance (Camilleri, 2022; Passetti & Tenucci, 2016). This standard encourages companies to achieve continuous improvements to minimise their environmental impact. Furthermore, this standard emphasises the significance of promoting environmentally responsible behaviour throughout the organisation and building relationships with various stakeholders. Many countries incentivise businesses across different economic sectors to reduce their emissions. For example, the European Union (EU) member states are expected to reduce their greenhouse gas (GHG) emissions by 40% before 2030 and 60% before 2050 (Camilleri, 2022). Additionally, many customers have become increasingly demanding, requiring ISO 14001 certification from the suppliers.

2.2.4 Sustainability tools

Sustainability tools are valuable resources that aid individuals, businesses, and organisations in measuring, managing, and enhancing their environmental, social, and economic sustainability initiatives. These tools offer frameworks, guidelines, and metrics to evaluate sustainability performance, establish objectives, monitor progress, and make informed decisions to minimise environmental impacts and promote sustainable practices. Below are some frequently utilised sustainability tools:

- Life Cycle Assessment (LCA): LCA is a tool for decision-making that evaluates the environmental costs and consequences of a product, process, or service throughout its entire life cycle - from design to disposal (Azapagic & Perdan, 2000).

- Sustainability Reporting Frameworks, such as the Global Reporting Initiative (GRI) or Sustainability Accounting Standards Board (SASB): It reports on sustainability performance and discloses relevant environmental, social, and governance information (Global Reporting Initiative, 2016). These frameworks promote transparency, accountability, and comparability of sustainability efforts across organisations, enabling stakeholders to make informed decisions.

- Environmental Management Systems (EMS): EMS are systematic approaches that assist organisations in managing and improving their environmental performance. The ISO 14001 standard is a well-known example of an EMS framework (ISO, 2015). EMS frameworks provide a structured framework for setting environmental objectives, conducting audits, and implementing continuous improvement measures. EMS tools enable organisations to reduce their environmental impacts and achieve sustainable practices.

2.2.5 Other concepts related to sustainability

In this dissertation, decisions were made based on Lean management principles while also considering their environmental impact. The environmental impact evaluation was based on the Circular Economy (CE) principles and Carbon Footprint (CFP) analysis.

2.2.5.1 Circular Economy

Over the years, the CE has gained significant momentum globally. However, the traditional linear economy based on the "take-make-dispose" model falls short of meeting the sustainability challenges of a world that seeks sustained economic growth, environmental protection, and societal well-being. With limited and finite resources on the planet, the rapid depletion of natural materials, and concerns about replacing them with synthetics, using and abusing the "perceived-to-be-abundant" resources for human needs is a severe problem. In addition, most end-of-life products and materials end up in landfills, exacerbating the issue (Jawahir & Bradley, 2016).

The CE's powerful concept is based on designing and implementing products and processes to improve resource efficiency, with circular material flow involving recovery, reuse, recycling, and remanufacturing of products. Therefore, Jawahir & Bradley (2016) defend that the CE is not an option but is inevitable for continued economic prosperity, ecological balance, and biodiversity preservation while maintaining human life and economic growth (Jawahir & Bradley, 2016).

Throughout history, the CE has strongly emphasised the principles of the 3Rs: Reduce, Reuse, and Recycle. Its goal is to achieve optimal production by utilising fewer natural resources and generating minimal pollution, emissions, and waste by applying these principles (Wu et al., 2014). The 3Rs were the foundation for green manufacturing derived from Lean manufacturing in the 1990s. Lean manufacturing was based on the 1R (Reduce) concept, which was introduced in the 1980s. Nowadays, it is evident that sustainable value in manufacturing can only be achieved through the combination of Lean and sustainable manufacturing. Therefore, three other Rs were added to provide a more comprehensive depiction: recover, re-design, and remanufacture, creating the 6 R's principles (Figure 5). These principles outline six strategies for achieving a CE and sustainable resource management. Each "R" represents a different action that can be taken to maximise the value of materials, minimise waste generation, and promote sustainable practices (Jaafar et al., 2007; Jawahir & Bradley, 2016).

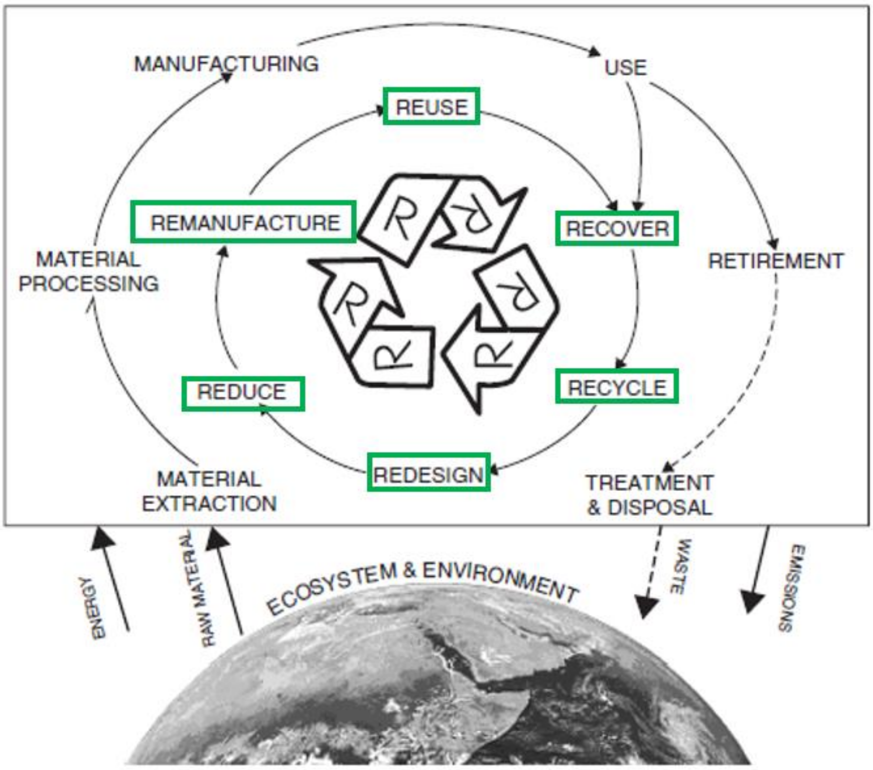


Figure 5 - The 6R's strategies
(Jaafar et al., 2007)

The 6 R's consists of (Jaafar et al., 2007):

1. Reuse: Instead of discarding products or materials after use, the principle of reuse promotes finding alternative ways to utilise them. This includes repairing, refurbishing, or repurposing items to extend their lifespan and minimise the need for new production.

2. Recover: Similar to remanufacturing, refurbishing involves repairing and restoring products to a usable condition, often with some cosmetic improvements. This strategy is commonly applied to electronic devices, furniture, and appliances.

3. Recycle: Recycling involves collecting and processing waste materials to transform them into new products or materials. This helps conserve resources, reduce energy consumption, and minimise landfill waste. Recycling can involve both traditional methods and advanced technologies.

4. Reduce: The first step is to reduce the consumption of resources and minimise waste generation by using fewer materials in the production and consumption processes. This can be achieved through efficient design, optimisation, and better planning.

5. Remanufacture: Remanufacturing involves restoring used products or components to their original specifications, ensuring they meet the same quality standards as new items. This process extends the life of products and reduces the demand for new manufacturing, thereby conserving resources.

6. Redesign: The final R encourages a shift in mindset and behaviour towards more sustainable consumption and production patterns. It involves questioning existing practices, adopting innovative approaches, and considering the lifecycle impacts of products and materials. Re-thinking helps identify opportunities for improvement and drives systemic changes towards a CE.

2.2.5.2 Carbon Footprint

In today's world, there is a growing concern about the impact of human activity on the environment, particularly in terms of carbon emissions. The amount of CO_2 and other Green House Gases (GHG) released into the atmosphere is known as the Carbon Footprint (CFP). It is a significant contributor to global warming and the depletion of natural resources. So, CFP is a tool that aims to quantify emissions associated with various activities, products, or organisations. This calculator measures emissions from energy consumption, transportation, and waste management, helping individuals and businesses assess their CFP and identify strategies for reducing emissions. In addition, by encouraging the adoption of low-carbon practices, these tools play a vital role in mitigating climate change (EPA, 2019). Within organisations, there are three distinct categories of GHG (Ghosh et al., 2020):

1. Direct emission: This measures the amount of GHG released into the environment due to various organisational activities, such as energy production. By implementing eco-friendly processes, these emissions can be reduced and controlled.

2. Indirect emission: This kind of emission is not controlled directly. The goods or services an organisation utilises or produces indirectly contribute to GHG emissions. For example, when transporting products or services from one location to another, the GHG emitted through the transportation mode can be regarded as an indirect emission.

3. Emission due to electricity: All companies require electricity to operate and must purchase it from various external sources. The most prominent sources of electricity globally are coal, natural gas, and nuclear energy. Although firms lack direct control over these sources, they still bear responsibility for the resulting emissions.

Nowadays, companies aim to calculate their CFP as part of their efforts to minimise and control it. This calculation can be a crucial first step in establishing an effective environmental management system and reducing carbon emissions.

This dissertation measured the GHG emissions associated with the materials consumed during production. It is important to note that these emissions are indirect, as they are not produced within the factory facilities but result from the company's demand for these materials. By evaluating the impact of these indirect emissions, it is possible to reduce the overall CFP and promote a more sustainable future. The measurement was based on the document prepared by the *Department for Environment, Food & Rural Affairs (DEFRA)* of the United Kingdom (DEFRA, 2022). So, the CFP saving is the product of the balance of the mass of the material saved and the conversion factor of the GHG of the respective material, which is present in kg CO_2 eq units. Therefore, the database supplied by DEFRA (Annex I) reflects the impact of the life cycle of the raw material (Figure 6) (DEFRA, 2022).

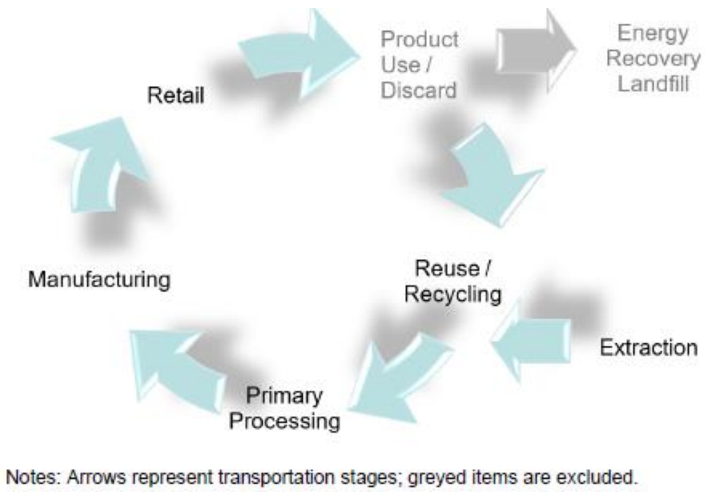


Figure 6 - Boundary of material consumption of the data sets
(Hill et al., 2020)

The material consumption conversion factors provided cover all GHG emissions from raw material extraction to the completion of the finished product for sale. Companies can utilise these factors to assess the potential influence of the products they acquire (DEFRA, 2022).

2.3 Eco-efficiency

This chapter delves into the critical concept of eco-efficiency and its significance in achieving sustainable development. The chapter explored various strategies and approaches that enable businesses and organizations to enhance their eco-efficiency performance.

2.3.1 Definition and Overview

The key to sustainable development is the concept of eco-efficiency, which emerged in the 1990s. Eco-efficiency refers to the ability of firms, industries, regions or economies to produce more goods and services with fewer impacts on the environment and less consumption of natural resources, linking the environmental impacts directly with economic performance (Caiado et al., 2017; Camarero et al., 2013; Moreira et al., 2010). The Organization for Economic Cooperation and Development (OECD) provide a broad definition of eco-efficiency as "the efficiency with which ecological resources are used to meet human needs", and the concept was popularised by the World Business Council for Sustainable Development (WBSCD) (Camarero et al., 2013). WBSCD defined eco-efficiency as " The delivery of competitively priced goods and services that satisfy human needs and bring the quality of life while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the Earth's estimated carrying capacity" ("World Business Council for Sustainable Development (WBCSD)," 1992).

Eco-efficient practices aim to minimise environmental impacts while maximising economic benefits. So, it becomes essential to organisations since it helps them to reduce costs and enhance their reputation by demonstrating their commitment to sustainability. The EU set eco-efficiency as one of the priorities for companies to reduce their ecological footprint and to integrate the measurement of environmental and economic performance (Passetti & Tenucci, 2016). Eco-efficiency improvement can involve a range of possibilities, such as the reduction of material intensity, energy intensity and toxic substance, the enhancement of recyclability, the maximisation of the use of renewables, the extension of product life and the increase of service intensity (Verfaillie, 2000).

The guide "Measuring eco-efficiency", published by WBCSD, suggests a framework to report a company's performance (European Environment Agency, 1999). This framework structures the eco-efficiency information in three organisation levels: categories, aspects, and indicators. Categories refer to broad areas of environmental impact or business value, such as the environmental impact during product creation. Aspects provide general information about a particular category and outline what needs to be measured, like material consumption. Indicators, on the other hand, are specific measures of an individual aspect that can be utilised to monitor and showcase performance, such as the quantity of CO_2 emissions in tonnes (Abreu, 2020)

Eco-efficiency measurement is the ratio between value-added and environmental impact added to a company's operational processes (Equation 1).

Equation 1 - Eco-efficiency

$$Eco - efficiency = \frac{Product\ or\ service\ value}{Environmental\ influence}$$

The economic return is usually monetary, such as added value or profit. However, environmental impact can be measured regarding resource consumption, emissions, or environmental damage (Passetti & Tenucci, 2016).

Eco-efficiency measurement has yet to gain universal acceptance. However, much criticism has arisen because eco-efficient is often concerned with reducing resources consumed to meet a social or environmental objective without questioning the trade-off between environmental and economic aspects (Passetti & Tenucci, 2016).

An eco-efficient strategy can help companies base their competitiveness on environmental-friendly practices, thus stimulating research and development investment and generating cost savings through reducing emissions and eliminating hazardous materials and waste production processes (Passetti & Tenucci, 2016).

Eco-efficiency may also involve cost reduction, which results from adapting innovative strategies and technologies intended to decrease energy and material usage (Passetti & Tenucci, 2016). Further, management accounting literature has demonstrated the link between future-oriented companies and the adoption of innovative management accounting tools. In this regard, eco-efficiency measurement may be considered an innovative environmental management accounting tool (Al-Omiri & Drury, 2007; Ferreira et al., 2010).

The eco-efficiency framework, which aims to maintain the balance of nature and its resources, incorporates seven essential elements (Hendrickson et al., 2006):

1. Reducing the material intensity
2. Reducing energy intensity
3. Decreasing the quantity and toxicity of substances
4. Promoting closed cycles and sustainable end-of-life strategies

5. Encouraging the use of renewable, local, and abundant resources
6. Improving product durability
7. Increasing the use of services.

Companies can increase their value proposition while minimising their environmental impact by fostering innovation in product development and production processes. Adopting a holistic approach to environmental performance assessment and implementing a systematic strategy to mitigate the adverse effects throughout a product's lifecycle is essential. This strategy can also help identify opportunities for improvement that might otherwise go unnoticed. An incremental improvement approach can generate gradual gains, while radical innovation can yield significant breakthroughs, including green logistics and alternative ownership models. The three main objectives of eco-efficiency are (European Environment Agency, 1999):

1. Promote sustainable resource management. Companies should reduce their energy, materials, water, and land consumption by enhancing product recyclability and durability, closing the product's life cycle and minimising waste.

2. Minimise the impact on the environment. Companies should reduce their emissions of air pollutants and discharges of water pollutants, limit waste disposal and avoid the dispersion of toxic substances. In addition, they can promote the sustainable use of renewable resources to preserve natural ecosystems.

3. Increase the value of their products or services. Companies can enhance product functionality, flexibility, and modularity and offer additional services such as maintenance, upgrading and exchange.

Incorporating eco-efficiency into a company involves exploring potential opportunities in four distinct areas (European Environment Agency, 1999):

1. Re-engineering processes: Companies can mitigate risks and promote sustainability by reducing resource consumption and pollution.

2. Re-valorisation of by-products: Finding innovative approaches to re-valorise by-products through the cooperation of other companies.

3. Re-designing products: Companies can be more eco-efficient by changing the products' geometry.

4. Re-thinking markets and re-shaping demand and supply: Companies can discover new ways of meeting customer needs.

2.3.2 Material Efficiency

In 2014, the production of the key materials accounted for 26 % of global energy consumption and 18 % of CO_2 emissions from fossil fuels and industrial processes. Material Efficiency (ME), which measures the amount of physical services provided per material unit, plays a crucial role in addressing climate change. ME strategies aim to achieve similar outcomes using fewer materials or materials with lower emissions. These strategies have obtained recognition as significant but largely unexplored opportunities for reducing emissions, including product light-massing, product lifespan extension, reuse, remanufacturing, material recycling, and appropriate material selection (Hertwich et al., 2019).

The interest in ME among policymakers has recently increased due to the popularity of the CE and concerns about plastic pollution in the oceans. However, it is only now that policymakers have started considering the potential synergies and trade-offs between ME and GHG mitigation (Hertwich et al., 2019).

A meeting organized by the Royal Academy offers the following definition: "'[ME] entails the pursuit of technical strategies, business models, consumer preferences and policy instruments that would lead to a substantial reduction in the production of high-volume energy-intensive materials required to deliver human wellbeing." (Allwood et al., 2013).

The literature describes the following strategies (Figure 7) (Hertwich et al., 2019):

1. Lifetime extension (including repair, resale, and remanufacturing): increasing the service provided by existing products.

2. Light-mass design and materials choice: reducing the material used and/or lowering GHG emissions during production.

3. Reusing components, including through remanufacturing and modularity.

4. Recycling, upcycling, and cascading.

5. Improving yield in production, fabrication, and waste processing.

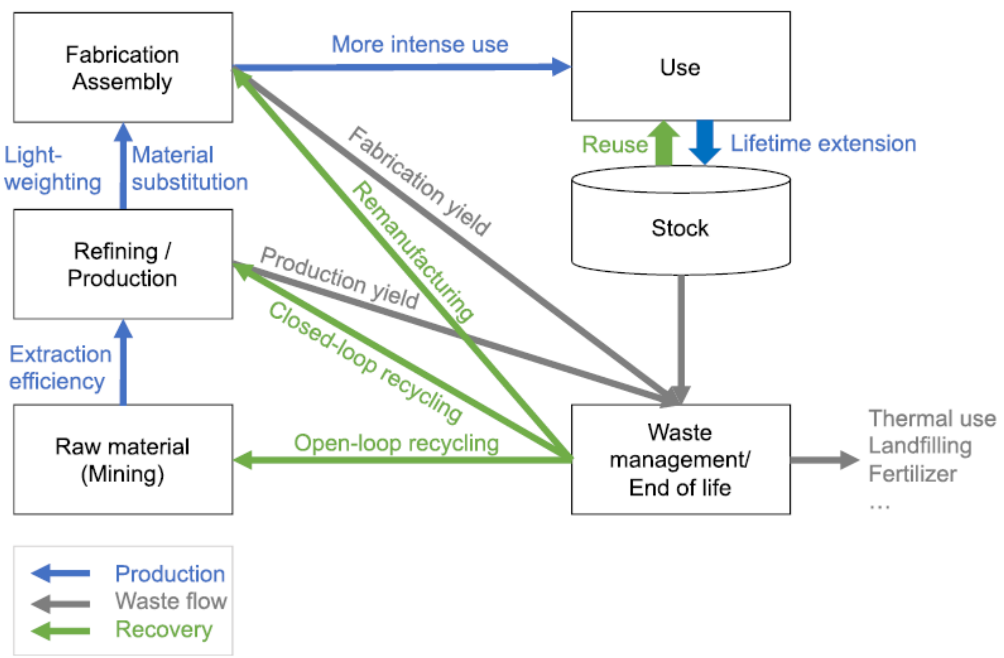


Figure 7 - Material cycles and the identification of material efficiency strategies.
(adapted from Hertwich et al., 2019)

ME refers to the amount of material used in the final product compared to the effort expended. As outlined by Greinacher et al. (2015), ME for a given product is calculated by dividing the value of the materials in the final product by the combined value of incoming materials across the product's value stream and the monetary costs of disposing of waste materials (Equation 2) (Greinacher et al., 2015).

Equation 2 - Material Efficiency

$$ME_{product\ A} = \frac{Output_{prod\ A} * CR\ raw_{prod\ A}}{Input\ raw_{prod\ A} * CR\ raw_{product\ A} + Output\ waste_{prod\ A} * CR\ waste_{prod\ A}}$$

With CR raw $_{prod\ A}$ and CR waste $_{prod\ A}$ being the cost rates per mass unit of raw material and disposal costs, respectively.

2.4 Lean - Green

This section will present the definitions and an overview of Lean–Green and the correlation between Lean methods and waste management.

2.4.1 Definition and Overview

The Lean approach aims to reduce waste, whereas the green approach focuses on minimising environmental impact. By merging the two, the Lean–Green approach can provide a structure to produce more sustainable and valuable products. Furthermore, by implementing both Lean and Green strategies, manufacturers can establish a solid environmental position that results in lower costs and risks, higher revenue, and a better brand image (Fercoq et al., 2016).

The statement "Lean is Green" has recently gained more popularity (Fercoq et al., 2016). However, the Lean–Green link has been investigated from 1990 onwards (Abreu et al., 2017; Maxwell et al., 1998). While the primary goal of Lean was not to tackle sustainability concerns, certain experts argue that its principles can provide several advantages for a more environmentally responsible industry. As an illustration, Yang et al. (2011) emphasised the correlation between these ideas. They observed that embracing a Lean attitude can also assist businesses in executing eco-friendly measures to reduce waste and pollutants (Yang et al., 2011). According to Steve Hope, the General Manager of Toyota Motor Europe, the company aims to be “green, clean and Lean”. As a result of this commitment, Toyota became the first automotive company worldwide to achieve "zero waste to landfill." (Fercoq et al., 2016).

Bergmiller & McCright (2009) has shown a positive correlation between Green operations and Lean results. Furthermore, companies that implement Green practices alongside Lean techniques have been found to achieve better results than those that do not. The Lean methodology serves as a catalyst and works synergistically with the Green strategy to deliver optimal outcomes (Bergmiller & McCright, 2009). Mollenkopf et al. (2010) suggest that Lean and Green's strategies are often compatible due to their shared focus on waste reduction (Mollenkopf et al., 2010). Dues et al. (2013) agree with this perspective but further note that the overlap between these paradigms extends beyond waste management to include considerations like the role of individuals and organisations, shortened lead times, improved supply chain relationships, and Key Performance Indicators (KPI) that prioritise service quality (Dues et al., 2013).

A study conducted by Fercoq et al. (2016) delved into integrating Lean and Green practices to reduce waste in manufacturing processes. The researchers utilised the design of experiments tool to evaluate the impact of the seven Lean wastes and the 3R hierarchy (Reduction/Reuse/Recovery) derived from the Lean and Green methodologies on solid waste management performance. The study concluded that combining both approaches in a Lean/Green matrix significantly improved the effectiveness of a solid waste management plan (Fercoq et al., 2016).

According to the literature, implementing Lean Thinking has continuously improved resource efficiency and reduced material, increasing ME and energy use. This, in turn, has helped to prevent and reduce environmental pollution. Businesses that have adopted Lean methods and operate highly efficiently have successfully prevented waste at the source rather than managing it once it has been generated. Researchers generally agree that Lean Production positively impacts waste minimisation and pollution prevention, particularly with manufacturing process efficiency and environmental performance. Therefore, expanding Lean initiatives to address environmental waste generation can improve environmental performance while positively impacting Lean manufacturing and Green initiatives (Caldera et al., 2017).

The primary common ground between the Lean and Green approaches is their emphasis on reducing waste. This can be observed through the concept of waste in Figure 8, which highlights the overlapping areas between the two approaches.

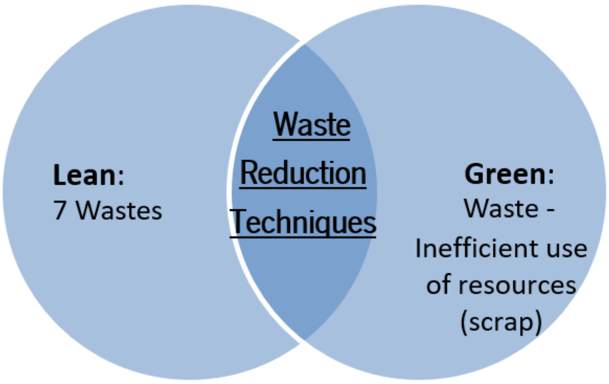


Figure 8 - Overlap of Lean and Green Paradigms
(Dues et al., 2013)

The Lean–Green concept combines the integration of value and efficiency from both operational and environmental perspectives. Lean focuses on enhancing operational value by actively eliminating waste, aligning with the fundamental principle that nothing in nature is wasted but instead transformed, meaning that the notion of waste becomes obsolete. Hence, adopting a Lean–Green approach can offer an ideal framework for producing environmentally friendly products and processes that are also highly valuable (Abreu et al., 2020).

Operational practices, provided by the Lean Philosophy, can play an essential role in facilitating and prioritising environmental responsibility. They can increase efficiency by reducing energy, water, and raw material consumption, thus minimising the environmental impacts of a company's products and processes. Operational practices can focus on designing and developing more environmentally conscious products. Examples include eliminating polluting and hazardous materials in products, reducing resource consumption in production and product usage, or facilitating disassembly, reusability and recyclability and remanufacturing. Integrated technology, such as renewable energy, can promote environmental-related operational practices or focus on reusable or recyclable packaging consumption. Operational procedures can contribute to eco-efficiency by reducing costs while increasing the environmental performance of organisations. As such, eco-efficiency measurement and operational practices should be linked to better support the decision-making process and performance evaluation (Passetti & Tenucci, 2016).

2.4.2 Lean methodologies and environmental sustainability

The Environmental Protection Agency (EPA) in the United States has been exploring the connection between Lean methodologies and environmental sustainability. They have published a variety of toolkits, including some focused on the intersection of Lean principles and environmental concerns, as well as others that examine the relationship between Lean and Six Sigma methodologies. Still, other resources explore applying Lean practices in specific contexts with environmental implications (Abreu, 2020). Among these toolkits, the environmental waste concept was defined in "The Lean and Environment Toolkit" (U.S.-EPA., 2007). Environmental waste is "any unnecessary use of resources or a substance released into the air, water, or land that could harm human health or the environment" (U.S.-EPA., 2007). Companies can utilise Lean tools to minimise environmental waste. This type of waste will be referred to as residues in this dissertation to differentiate it from Lean waste. Such residues have the potential to emerge throughout the manufacturing and distribution process, as well as when customers utilise and discard the products and services. (U.S.-EPA., 2007).

In terms of day-by-day practice, companies will encounter residues, such as:

- Energy, water, or raw materials are consumed excessively to meet customer desires.
- Pollutants and material wastes are released into the environment, such as air emissions, wastewater discharges, hazardous wastes, and solid wastes.
- Hazardous substances that unfavourably affect human health or the environment during production or product presence.

Like other Lean wastes, the residues do not add value for customers but create costs for companies and society. For instance, when hazardous materials are released into the environment, it becomes a residue. While residue is not included in the TPS' seven wastes, it does not mean that the "deadly" Lean wastes are unrelated to the environment (U.S.-EPA., 2007).

Table 1 outlines the environmental impacts associated with the Lean wastes that Lean methods aim to address (U.S.-EPA., 2003).

Table 1 - Environmental Impacts of Lean Wastes (U.S.-EPA., 2003)

Waste type	Examples	Environmental impacts
Overproduction	Manufacturing items for which there are no orders	- Unnecessary products require additional raw materials and energy consumption during manufacturing. - Additional items may run the risk of spoiling or becoming outdated. - Extra hazardous materials use results in emissions, waste disposal, worker exposure, etc.
Inventory	Excess raw material, WIP, or finished goods	- More packaging to store work-in-process (WIP) - Waste from deterioration or damage to stored WIP - More materials are needed to replace damaged WIP - More energy used to heat, cool, and light inventory space
Transportation and Motion	Human motions that are unnecessary or straining, and WIP transporting long distances	- More energy is used for transport. - Emissions from transport - More space is required for WIP movement, increasing lighting, heating, and cooling demand and energy consumption. - More packaging is required to protect components during movement. - Damage and spills during transport - Transportation of hazardous materials requires special shipping and packaging to prevent risk during accidents.
Defects	Scrap, rework, replacement production, inspection	- Raw materials and energy are consumed in making defective products. - Defective components require recycling or disposal. - More space is required for rework and repair, increasing energy use for heating, cooling, and lighting.
Over-processing	More parts, process steps, or time than necessary to meet customer needs	- More parts and raw materials consumed per unit of production - Unnecessary processing increases waste, energy use, and emissions
Waiting	Stock-outs, lot processing delays, capacity bottlenecks, equipment downtime	- Potential material spoilage or component damage causes waste - Waste energy from heating, cooling, and lighting during production downtime
Unused creativity	Long time, ideas, skills, improvements, and suggestions from employees	- Fewer suggestions for pollution prevention and waste minimisation opportunities

As per the U.S.-EPA. (2007), incorporating environmental performance metrics into Lean efforts facilitates managers in identifying essential areas for improvement. These metrics encompass energy, material, water consumption, air emissions, water pollution, wastewater, and hazardous and non-hazardous solid waste (U.S.-EPA., 2007).

While monetary evaluation is the main decision criterion for manufacturing systems, it is insufficient. Non-monetary values should also be considered; specific limits and evaluations for each product are necessary. Simply allocating overall costs and resource consumption based on the quantity of products manufactured does not address the underlying relationships and sources of waste. To effectively improve manufacturing processes, it is crucial to consider the costs and resource consumption at the specific points within the product's value stream. This approach enables the deduction of appropriate improvement strategies (Greinacher et al., 2015).

2.5 Residues

The residues generated from industrial activities and consumer consumption have become a significant environmental concern in modern society. As industrialized nations continue to exploit natural resources to meet various needs, the volume of waste produced has reached unprecedented levels, leading to pollution and ecological imbalances.

This chapter aims to explore the concept of residue management. By delving into the complexities of residue management, it is possible to identify strategies and practices that promote sustainable waste management, resource conservation, and a cleaner environment.

2.5.1 Residues management

Industrialized nations extensively exploit natural resources from the environment to fulfil their diverse needs, ranging from essential to extravagant. Consequently, the substantial production volume gives rise to pollution, which often finds its way back into the environment as waste (Kollikkathara et al., 2009). *Decreto-Lei n.o* 178/2006 defines Waste as any substance or object that the possessor discards, intends, or is obliged to discard (...). Kollikkathara et al. (2009) perceive waste as a "resource that is simply out of place," emphasizing the need for effective management to maximize its value.

According to Williams (2005), the waste strategy outlined by the European Union revolves around a fundamental concept known as the "hierarchy of management operations.". This concept, illustrated in Figure 9, offers a novel approach to waste management, enabling the identification of diverse strategies and their relative significance. Prevention and Reduction occupy the highest position in this framework, signifying their utmost importance. Subsequently, reuse is prioritized, followed by recycling or alternative forms of valorisation when reusing is unfeasible. Disposal should be viewed as the last resort for waste management. This principle aims to minimize waste disposal in landfills with the potential for recycling and recovery (as stipulated by Decreto-Lei n.º 183/2009).

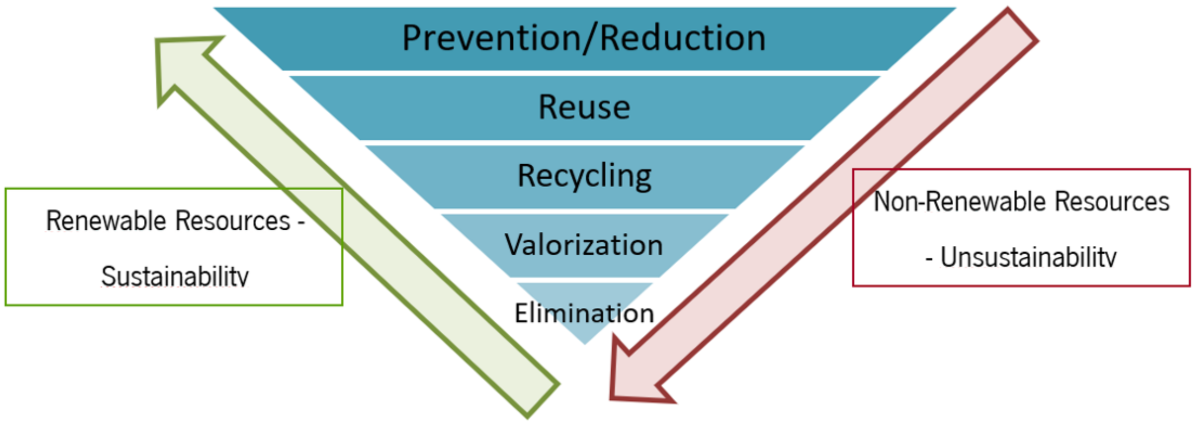


Figure 9 - The Hierarchy Principle in Waste Management Options
(adapted from Maczulak, 2010)

The valorisation process encompasses three key aspects: material, organic, and energetic valorisation. Material recovery primarily involves recycling and transforming waste materials into new products. Organic recovery focuses on converting the organic fraction of waste into substances like soil-like compounds or biogas, which have various applications. Energy recovery involves harnessing the energy potential of waste through incineration or the combustion of generated gases (Lipor, 2009)

Landfilling remains the predominant method of waste disposal. In this process, the biodegradable fraction of waste undergoes biological decomposition, neutralization, and stabilization, resulting in an inert material. However, leachates and GHG such as methane and carbon dioxide are released as decomposition progresses. Consequently, waste disposal in landfills should be considered the last option within the hierarchy of waste management options (Williams, 2005).

The *Lista Europeia de Resíduos* (LER), which replaced the European Waste Catalogue, is a comprehensive document aimed at harmonising the classification and identification of waste within the European region. The LER provides a categorized listing of various types of waste based on their origin. Annex II presents the enumeration of the operation of disposal and recovery procedures applicable to the different waste types (the document is in Portuguese because they are according to *Portaria n. 209/2004*).

2.5.2 Plastic residues

The industry where Stokvis Celix acts is very challenging. In fact, the issue of plastic pollution has become a major global concern, leading the EU to prioritize waste management measures that prioritize prevention and reuse. The hazardous nature of plastic and its ability to infiltrate ecosystems has led some to view it as a planetary boundary and systemic risk. Global plastic production has doubled over the past two decades and is projected to double again in the next two decades. Plastic has become ubiquitous daily, and some economic stakeholders have attempted to shift blame onto consumers for the escalating plastic residues issue. However, political actions rarely hold producers accountable for the environmental impact of their products or effectively regulate plastic production. Residues management approaches, such as recycling and proper disposal, are the predominant global approaches, but residue prevention measures involving all responsible stakeholders are crucial. Many residues in the EU are still incinerated or sent to landfills. While residue incineration is sometimes used for energy generation, it perpetuates reliance on continuous residue flow to incineration facilities, hindering recycling and prevention efforts. Only 30% of EU plastic waste is collected for recycling, and half is exported to countries outside the EU for processing. The EU's existing measures predominantly focus on residue treatment, such as recycling, energy recovery, and proper disposal, while neglecting the importance of residue prevention emphasised in the residue management hierarchy (Steinhorst & Beyerl, 2021)

At Stokvis, most residues are foam scraps, rubbers, and adhesives. Nowadays, companies need to implement the principles of the R’s. However, recycling these types of scraps has several challenges.

One of the main challenges of recycling foams is the lack of infrastructure and technology for foam recycling, which can be expensive to acquire and maintain. Additionally, foam is a lightmass material, making transportation and storage of foam for recycling challenging. These challenges lead to little demand for recycled foam products, which can be a barrier to recycling (Hopewell et al., 2009).

Recycling rubbers also presents several challenges. One of the primary challenges is the lack of awareness and education about rubber recycling. Rubber is a complex material, and the different types of rubber require different recycling processes. Another challenge is the limited market for recycled rubber products. While recycled rubber can be used in products such as playground surfaces, rubber mats, and athletic tracks, the demand for these products is limited, making it difficult to recycle rubber waste (Sato, 2018).

Lastly, adhesive recycling is also challenging due to its variety and the limited technology for recycling. In fact, recycling adhesives requires specialized equipment and technology, and there are limited options for recycling adhesives. Additionally, some adhesives can release toxic chemicals when recycled, harming the environment and human health (Shu & Huang, 2014).

While recycling foams, rubbers, and adhesives can be challenging, it is essential to overcome these challenges to conserve resources and reduce waste.

3 Company presentation

This chapter intends to present the company and the department where the project was developed in this dissertation. – Stokvis Celix Portugal, Lda. Starting with a brief contextualisation of the group, it follows the factory's presentation, its activity area, products, and main customers.

3.1 Identification and localisation

Stokvis Celix Portugal, Lda is a company based in Braga specialising in transforming flexible foamed cellular plastics and rubbers. They offer a variety of products that can be supplied in different formats to meet the specific requirements of their customers. Although their products can be used in various industries, they mainly cater to the automotive industry. Stokvis Celix Portugal, Lda is now a part of the US multinational ITW – Illinois Tools Works, specifically the Power Systems & Electronics (PSE) segment.

3.2 Story and evolution of Stokvis Celix Portugal, Lda

Stokvis Celix Portugal, Lda, has undergone several transformations to achieve its present-day status.

In 1998, José Gonzalez Raton and Augusto Manuel Lucas de Miranda founded the company in Braga under the name *Braxicel - Transformadora de Foam Técnicas, Lda*. Since then, the company has thrived with the support of its automotive sector clients. Towards the end of 2000, *Flexicel, S.A.,* a Spanish company engaged in the same industry sector, acquired two-thirds of the company's shares.

In November 2003, the company moved to its current location, the Parque Industrial de Sequeira, in the municipality of Braga. Over the years, it has expanded its operations in this facility, which houses its entire production process, including its laboratory, engineering and development department, financial area, administrative area, and raw material and finished product storage. The company also has advanced warehouses for finished products in logistics centres in Spain and France.

In 2005, the company decided to focus solely on producing components for the automotive industry and changed its name to *Celix - Transformadora de Espumas Técnicas, Lda*. A year later, the Dutch group, *Stokvis Tapes*, acquired the company’s entire share capital, bringing in new production strategies and business concepts. As a result of its integration into the *Stokvis Tapes Group*, the company changed its name to *Stokvis Celix Portugal Unipessoal, Lda*, which it still holds today.

In 2008, the Stokvis Tapes group was acquired by the North American multinational *ITW - Illinois Tools Works*, which currently includes the group's Power Systems & Electronics segment. Since then, Stokvis Celix has been working towards becoming a global enterprise, which has been the management's strategic objective.

3.3 ITW and Stokvis Tapes Group

ITW, a leading manufacturer of speciality industrial equipment, consumables, and related services, was established over a century ago. With a significant presence in developed and emerging markets, ITW serves customers worldwide through its operations in 57 countries. The company employs over 100,000 people and strives to satisfy its customers by constantly innovating its products.

The Stokvis Tapes group, with more than 50 years of experience in the adhesives industry, has gained a strong reputation for developing solutions for insulation, protection, sealing, shielding, and packaging applications. It primarily operates in the automotive industry and has production facilities in over 20 countries, making it a multinational group. Figure 8 highlights the main units of Stokvis Tapes in red.

Figure 10 - Stokvis Tapes Group

The combination of ITW and Stokvis Tapes creates a unique global platform in tape and foam production, and the group is dedicated to developing innovative solutions in the tape industry. Furthermore, with its international presence, Stokvis Tapes can provide its customers with a perfect combination of local presence and international experience.

3.4 Raw materials and main suppliers

At Stokvis Celix Portugal, our main raw materials are foamed rubbers and plastics, called base materials and adhesives. Typically, the base materials and adhesives are purchased separately and combined through the adhesive operation during production. However, it is also possible to purchase and work with the base materials directly, including those that already have adhesive included.

The principle base raw materials used are categorised as Polyvinyl chloride (PVC), Polyurethane (PUR), Ethylene Propylene Diene Monomer (EPDM), Felts, Taka, Polyethylene (PE) and PE + Polyethylene Terephthalate (PET) each with subcategories that vary in thickness, length, and characteristics. The choice of adhesive depends on our customers' specific needs, and a wide variety is available. Figure 11 provides a visual representation of the raw materials used.

Figure 11 - Principle Raw materials

Stokvis works with various companies regarding suppliers, but Figure 12 highlights the ones that Stokvis most rely on.

Figure 12 – Principle suppliers of Stokvis Celix Portugal

3.5 Products and main customers

Stokvis Celix offers a diverse range of products suitable for various production sectors, specifically the automotive sector. These products are designed with insulation, anti-noise, and protection properties. They are crafted by transforming foamed plastics and rubbers to supply customised products in different formats tailored to their customers' needs. The products are commonly used in wiring coverings, mirror joints, seat or dashboard coverings, front panel insulation, and car door insulation. Customers can choose from three different supply options, depending on their intended use: in roll format, in multiple formats added to the adhesive, or in separate pieces with and without adhesive. Refer to Figure 13 for an illustration of these options.

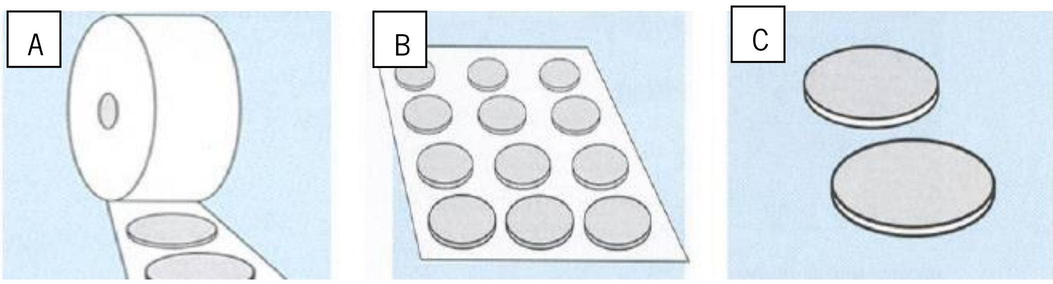


Figure 13 - Type of products supplied: (A) Roll format; (B) Multiple formats added to the adhesive; (C) Separated pieces

Stokvis Celix Portugal is committed to catering mainly for the automotive industry, primarily focusing on satisfying its customers. The major brands it serves include the Daimler Group, the PSA Group, Volkswagen, Seat and Audi. The company also offers its services to manufacturers of automotive components, such as Faurecia, Sitooles Group, Denso, Yazaki, Antolin Group, Eurostyle Systems, Fico Cables, Calsonic Kansei and Aspock Systems. Additionally, Stokvis Celix provides its expertise to other companies associated with the ITW group or the Stokvis Tapes group. Figure 14 represents all these customers.

Figure 14 - Principle customers of Stokvis Celix Portugal

3.6 Production processes

This section provides a concise overview of the production system of the company, which comprises seven different sectors, distributed on 5 warehouses: 1) Raw materials receiving warehouse, 2) Adhesive, 3) CNC cutting lathe, 4) Total cutting section, 5) Partial cutting section, 6) Assembly, and 7) Shipping. Each sector plays a vital role in the production process of the products. Figure 15 provides the general layout of the production system.

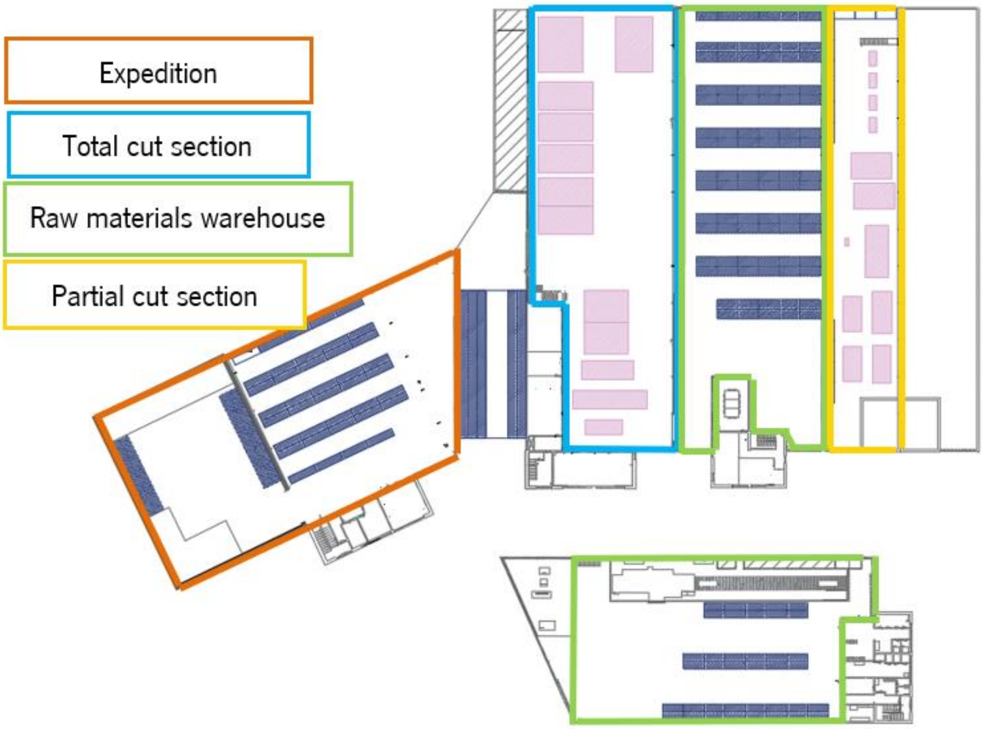


Figure 15 - Layout of the company

3.6.1 Raw materials reception

The production process commences at the reception warehouse upon receiving raw materials. First, these materials are placed in a quarantine zone for inspection to ensure that any defective items are not supplied to production. If the materials comply with standards, they are labelled and assigned a position in the warehouse. Then, the raw materials are distributed to various production sectors based on production planning needs and schedules.

3.6.2 Adhesive process

The adhesive process, known as laminating process, represented in Figure 16, is the first step in which the raw materials that do not contain adhesive are joined with the adhesive, if required, for the final product.

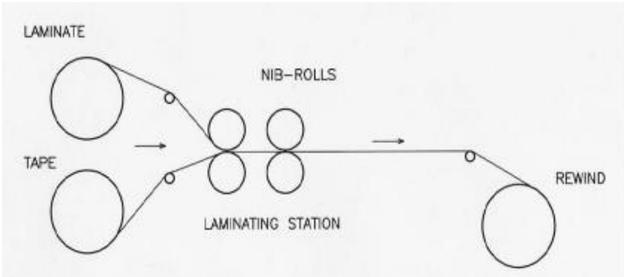


Figure 16 - Laminating process

The laminating equipment, shown in Figure 17, unrolls the adhesive and base material, applying heat and pressure to create better adhesion between the two materials.

Figure 17 - Laminating equipment

3.6.3 Slitting process

As shown in Figure 18, the Slitting process involves cutting high-width rolls into smaller-width rolls with high precision using a CMC cutting lathe. This process is necessary to minimise material waste and to accommodate the downstream process's size limitations.

Figure 18 - Slitting process

3.6.4 Cut

The cut process can be total cut, known as die cut, or partial cut, known as kiss cut. For this, it is used as a cut tool. There are three types of cutting tools. Two of them do a vertical movement, where one is in a fixed head and the other the head rotated. The third type of cutting tool is rotative. These three types are represented in Figure 19.

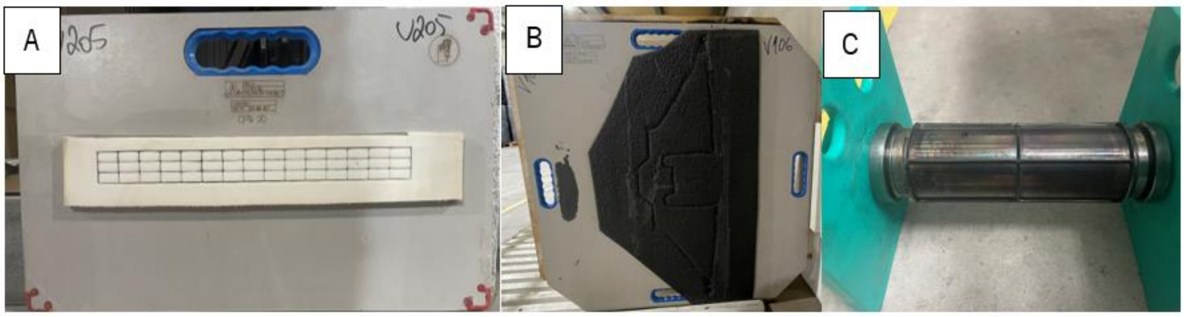


Figure 19 - Tool: A) Fixed head; B) Rotate head; C) Rotation equipment

3.6.4.1 Total cut

In the total cut section, also known as die cut, rolls or plates, the base material, with or without adhesive, undergo cutting into desired shapes and dimensions. The process involves passing the blade through the base material, adhesive, and adhesive paper (liner). The process is represented in Figure 20.

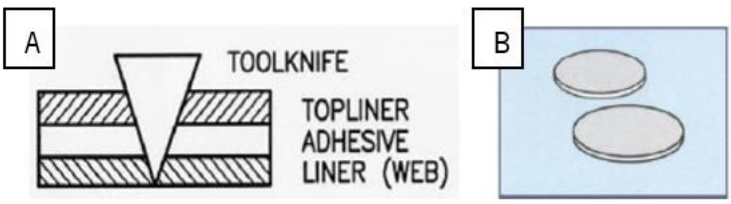


Figure 20 - Total cut: (A) scheme of the process; (B) Final pieces

The equipment that does total cuts can have a fixed head, or this can rotate. These equipment are chosen according to the best yield and piece dimension.

3.6.4.2 Partial cut process

The partial cut section involves the process of crossing the tool's blade over the base material and adhesive without perforating the latter's paper, as shown in Figure 21. This section caters to producing parts with the desired shape and dimensions, respecting the limitations of the equipment and the adhesive roll format.

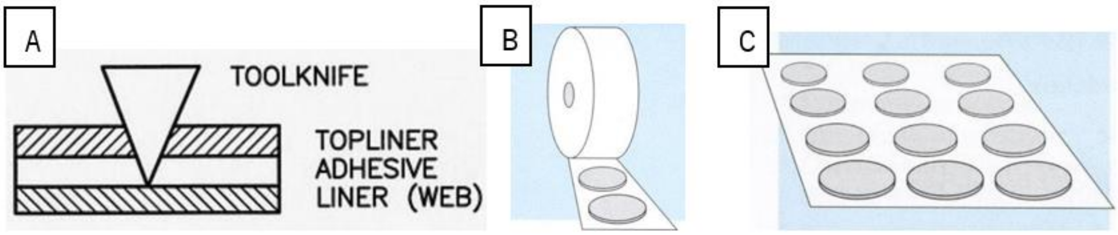


Figure 21 - Total cut: (A) scheme of the process; (B) Final pieces in roll; (C) Final pieces in sheets

3.6.5 Assembly section

The assembly section involves various operations such as removing waste from the parts, applying post-cut adhesive, assembling the parts, and packaging them according to the customer's specifications.

3.6.6 Dispatch section

The dispatch warehouse and the finished products arrive from the production zone, are allocated in the dispatch warehouse, and are dispatched based on the customer orders and schedule.

4 Description and critical analysis

This chapter focuses on the description and critical analysis of the material consumption of one sector of the factory and on the management of the residues. A critical analysis was conducted, utilizing diagnostic tools, to identify the main associated problems.

4.1 Description of the productive process

Stokvis Celix Portugal's facilities are divided into seven sections, as represented in Figure 15 of Chapter 3, where five are destined for production. This dissertation project was carried out, mainly in the total cut section, specifically on six equipment highlighted in Figure 22. Due to confidentiality, the equipment will be named 1, 2, 3, 4, 5, and 6 during this research project.

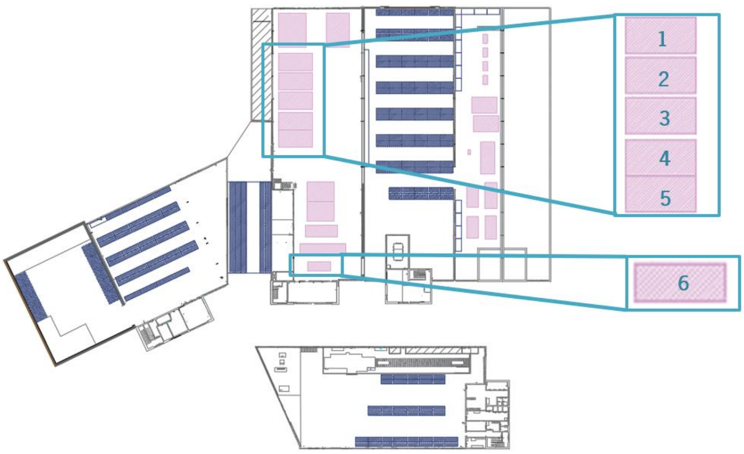


Figure 22 - Layout of Stokvis Celix, highlighting the equipment 1, 2, 3, 4, 5 and 6 in the cut section.

4.1.1 Operation in equipment 1, 2, 3, 4 and 5

The equipment numbered 1 - 5 use tools with blades, which apply pressure on the raw material, cutting it and creating the products with the shape requested by the customer. The distance between each cut is known as the pace. The tools of the different equipment have different movements. Equipment 1, 2 and 3 operate in the same manner. The tool is fixed and has only vertical movements. However, for equipment 4 and 5, the tool's head functions similarly in these equipments, moving vertically, horizontally and rotates. In this case, the tool's head moves to adjust the pace in all directions. Figure 23 illustrates the process both processes.

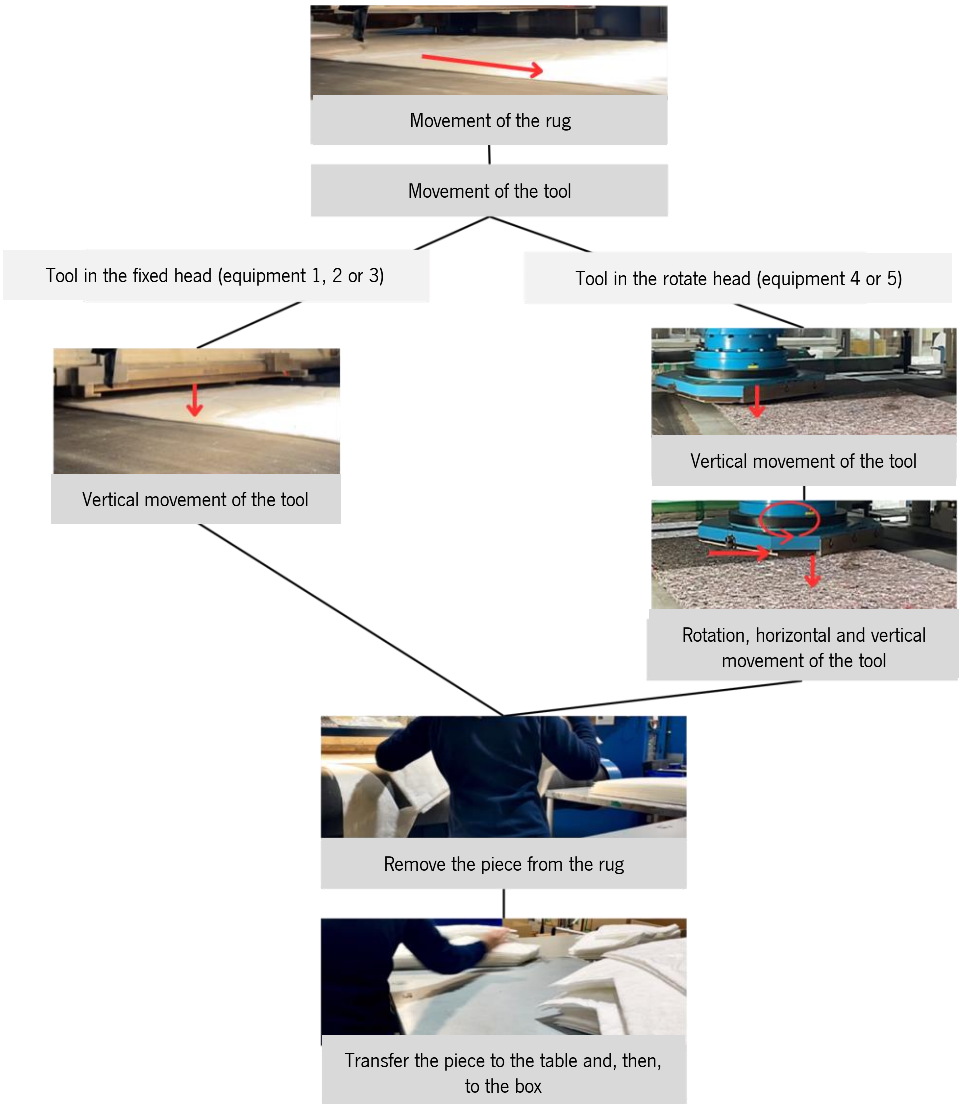


Figure 23 – Cut process of equipment 1, 2, 3, 4 and 5

Equipment with a fixed head could produced more pieces per beat and can produce larger pieces, but their performance suffered when dealing with irregular pieces. On the other hand, equipment with rotating heads can better use material space. Figure 24 provides an example of different tools and their distribution. In these cases, the tool in the fixed head can produce 14 pieces per beat, while the tool used with rotating head equipment can produce only one piece per beat. However, the rotation feature allowed for better material yield in the case of this piece.

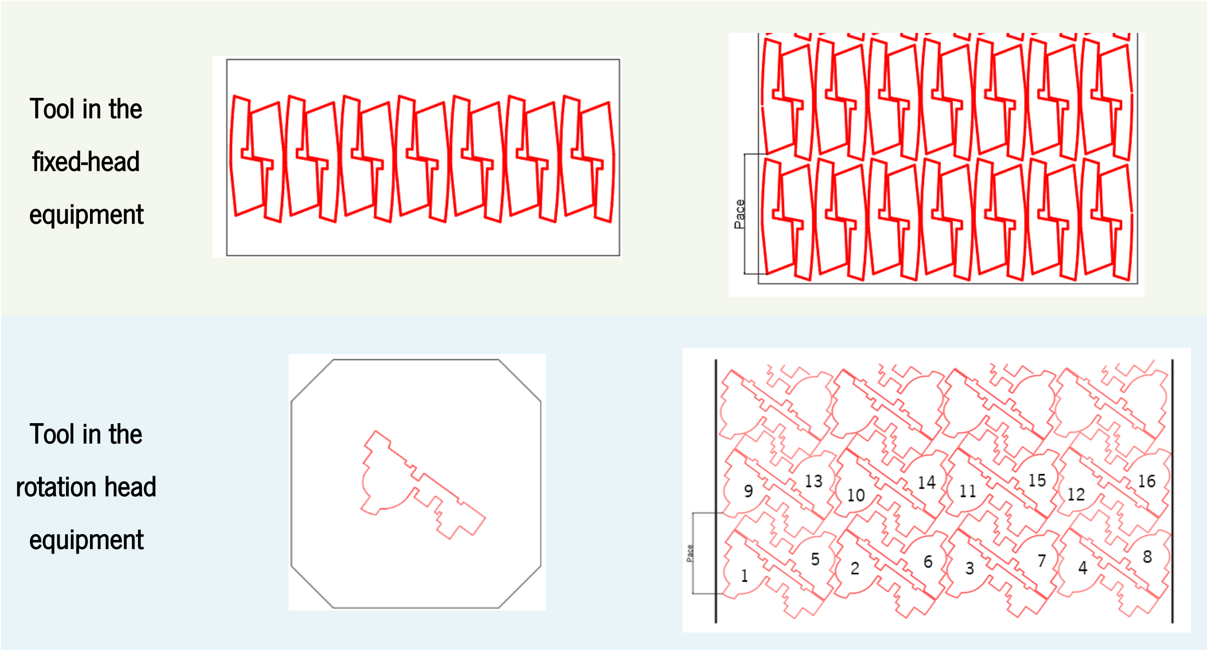


Figure 24 - Examples of the different tools and their application on the material

Depending on the complexity of the product and its packaging requirements, these equipment can accommodate one or two workers. When two workers are involved, one is responsible for removing the pieces from the rug, while the other handles tasks such as disposing of internal waste and packaging the pieces.

4.1.2 Operation on Equipment 6

Equipment 6 produces strips, and its process is described in Figure 25.

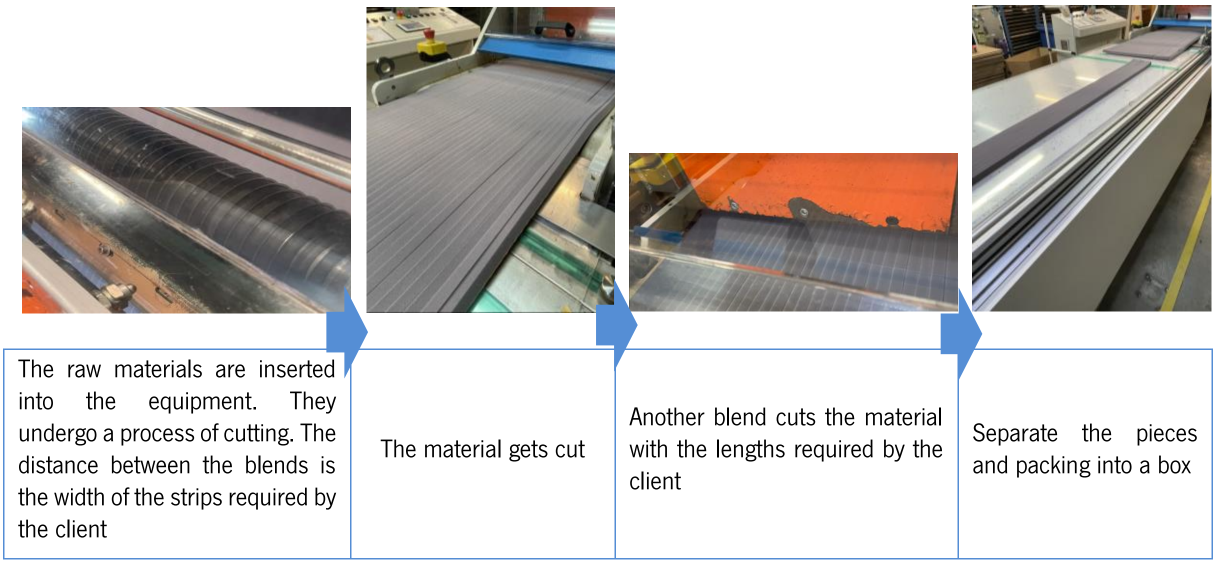


Figure 25 - The cutting process of equipment 6

Equipment 6 is operated by a single worker responsible for packaging the pieces.

4.2 Tool review

The engineering team reviews the tools during non-busy periods to improve the yield. A high yield is crucial, enabling the company to save on materials and resulting in economic savings. If the yield is improved, the tool is ordered and tested in the equipment. If it performs well, it is inserted into the system and becomes the tool used for future productions. If necessary, the old tool continues on the production floor and is used as a substitute.

4.3 Description of the waste management

The residues produced by the company were mainly raw material scraps. In 2022, on average, residues produced 38 320 kg per month. These residues have a CFP of 119 416 kg CO_2 eq per month. Because Stokvis did not track residue mass for each type of raw material, the CFP calculation was based on the average GHG conversion factor for plastics, which was 3 116.29 kg CO_2 eq/ton of plastic.

Due to the complexity of recycling these materials and the logistical difficulty of separating them during production, the company did not recycle them. As a result, all the different materials are placed into the same container. Figure 26 presents an example of scrap and the container of residue.

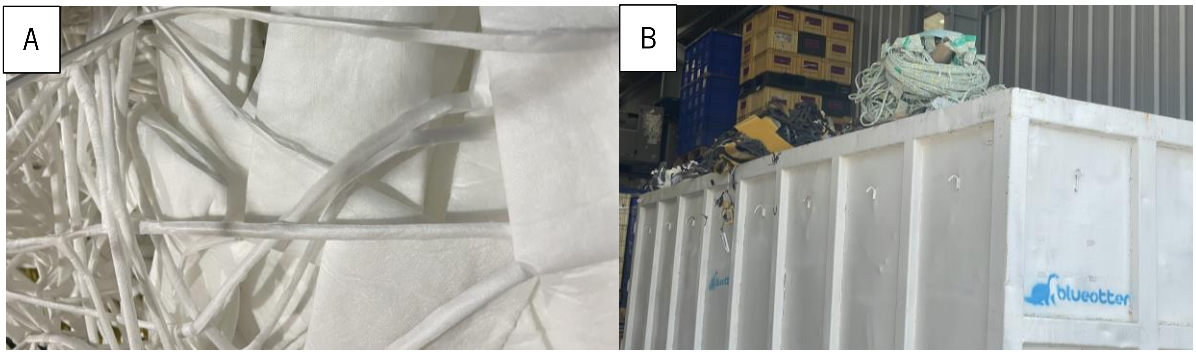


Figure 26 – Residues produced by Stokvis Celix: A) Scraps from production; B) Residues container.

In addition, the company possesses a considerable quantity of leftover cardboard boxes, card tubes, plastic film, and plastic bags, which are indirect production residues. Unfortunately, this waste category was unmonitored, leading to the company's absence of documented mass records.

The flow of the residues of the raw materials and the cardboard and plastic collection is represented in the spaghetti diagram on the factory layout in Figure 27.

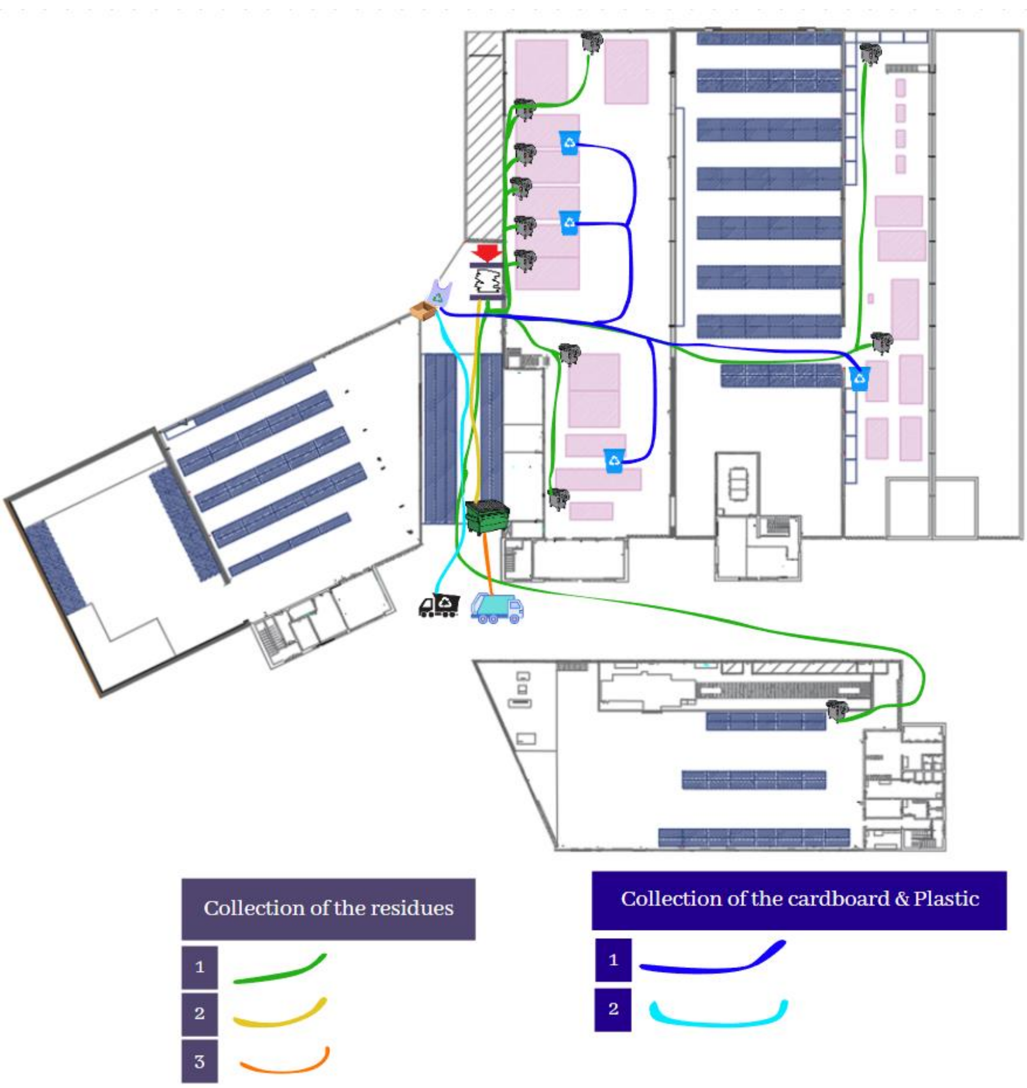


Figure 27 - Spaghetti diagram on the layout of the factory

4.3.1 Residues resulted directly from the production

The collection process of the residue resulting directly from production gets through several stages, which are represented in Figure 28.

The residues accumulate on the floor while the pieces are collected from the rug	The equipment worker stops the equipment and collects it from the floor to the nearest trash	The trash is collected by another worker, which compresses the residues	The bale of rubbish goes to the container, which will be collected every day by a truck

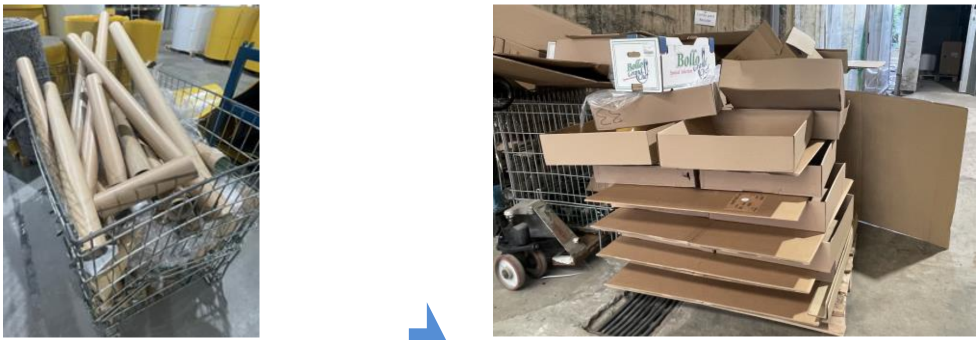
Figure 28 - Stages of the residues collection

Collecting containers incurs costs for the company. The company associated with Stokvis charges for each transportation and per ton of residues that must be treated. In 2022 the average cost wasan 5 012 €/month. Due to the nancial world situation, the prices of transportation and treatment increased. In 2023, it increased by 26 % per transport and 43 % per ton treated.

The residues produced did not end up in landfills. Instead, it was incinerated to produce energy. The code of 'Waste disposal and recovery operations' of Stokvis is R12 ("*Troca de resíduos com vista a submetê-los a uma das operações enumeradas de R1 a R11"*) (Annex II).

4.3.2 Indirect residues of the production

Collecting the indirect residues from production (cardboard, plastic bag, and film) had a more straightforward collection process, presented in Figure 29.



The employees accumulate the card and the plastics in the trash. Two equipment share one of these trash

Transportation and accumulation of these residues on the proper local for then be collected by a different truck of the raw materials residues

Figure 29 - Collection of the cardboard and the plastics

Stokvis generated no revenue or profit from collecting cardboard, plastic film, and plastic bags. Additionally, there was no record of the treatment these waste residues received.

The code of 'Waste disposal and recovery operations' of Stokvis is R13 ("*Acumulação de resíduos destinados a uma das operações enumeradas de R1 a R12 (com exclusão do armazenamento temporário, antes da recolha, no local onde esta é efectuada"*)) (Annex II). So, they cannot guarantee that the materials are recycled.

4.4 Critical analysis and problems identification

This section will critically analyse the management of the material and the residues resulting from production. It is presented an analysis from consuming material until the end of life of the residues. Through the critical analysis, several problems were identified.

4.4.1 High material consumption

Reducing the consumption of raw materials can significantly impact a company's economic and environmental sustainability. The company can save money and promote environmental conservation by doing so.

In 2022, Stokvis purchased 1 261.513 tons of materials, equivalent to 3 931.41 tons of CO_2 eq. Figure 30 illustrates the mass of each material consumed in 2022 and its corresponding CFP.

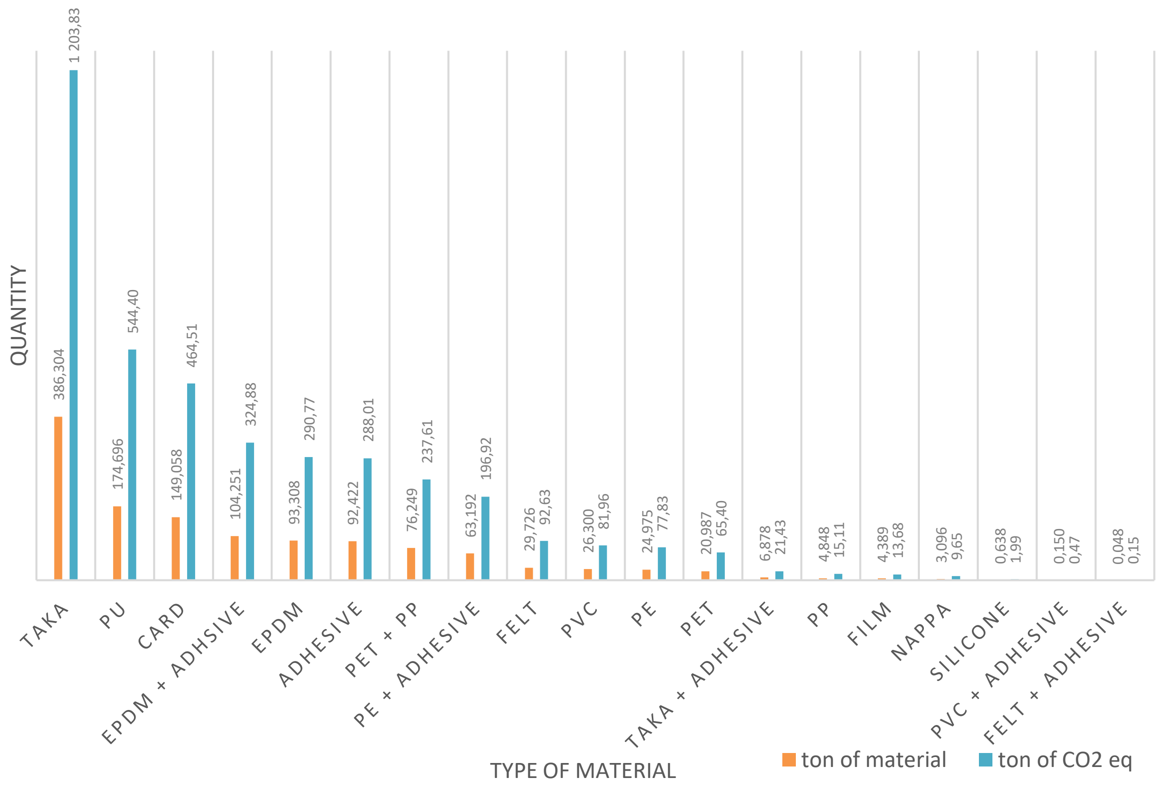


Figure 30 - The mass of material order in 2022 and its equivalent to Carbon Footprint

In 2022, Stokvis produced 459.840 tons of waste, accounting for 36.5 % of the materials purchased. As a result, 36.5 % of the costs incurred by Stokvis for materials were essentially wasted. Moreover, Stokvis, besides not having any profit from this purchase, also incurred additional expenses to dispose of these residues.

Excessive material consumption incurred additional costs beyond the cost of the material itself. It impacts the expenses related to waste disposal containers, equipment, and labour. Inefficient use of material by the tools results in the need for more material to produce the same number of pieces, requiring more rolls of material. To substitute the roll on the equipment, the worker must stop it from changing, which wastes time and increases costs. So, to determine these costs, a multi-moment analysis was developed, represented in Appendix I. On average, changing a roll required 217 s, equivalent to 3 min and 36 s. Therefore, Table 2 provides information on the cost of labour and equipment per change per roll. Additionally, it presents the total cost, which is determined by summing up the labour and equipment costs. The number of workers associated with each equipment may vary depending on the specific task requirements.

Table 2 - Labour and equipment costs per change per roll

Labour and Equipment	**Cost** (€/change/roll)	**Total (Labour plus Equipment costs)** (€/change/roll)
Labour (per worker)	0.84	-
Equipment 1, 2 or 3 (Fixed head equipment)	1.08	1 worker: 1.92 2 workers: 2.76
Equipment 4 or 5 (Rotate head equipment)	1.20	1 worker: 2.04 2 workers: 2.88
Equipment 6 (Strips equipment)	1.20	1 worker: 2.04

4.4.2 Difficulty in tool improvement

There were two main difficulties in doing tool improvements.

Firstly, the tools should be analysed periodically to improve the tools, redesigning them, leading to better yields. However, tool analysis was only conducted when the team had the time. Also, the calculation of the saving of references was analysed case by case, not having a written standardized procedure. The analysis criteria should be standardised, and the yield, waste production costs, sales volume, and the project's longevity should be considered. Unfortunately, all this information was scattered across several databases, making analysis difficult.

Secondly, when the revised tool arrived at the company, it was introduced into the system, and the workers should produce the piece with the new tool. However, sometimes this did not happen. Supposing a worker finds it challenging to collect the pieces from the rug with the new tool due to the different configuration of the distribution of the pieces during the first test. In that case, sometimes they will revert to the old tool for subsequent orders, even if the manufacturing order specifies the new tool, not always communicating to the superiors. This problem arises due to poor communication between the technical team and the production workers, leading to workers sometimes disregarding the improvement measures implemented and using their own procedures instead of following established standardized work defined by the technical team.

4.4.3 Disorganisation of the management of the residues

As previously stated, Stokvis produces a substantial monthly residue of 38 320 kilograms, primarily in the form of foam, rubber, and adhesive scraps. At the time of this project, the residues were incinerated and had an operation code of discard of R 12. However, in today's world, companies must abide by the principles of the 6 R's. Therefore, they should establish a recycling system after reducing material consumption and waste production. Nonetheless, recycling the types of residues processed in Stokvis poses several challenges.

Apart from the generated scraps, there were additional residues to consider. Specifically, cardboard boxes were utilized for specific roll packages, while others were safeguarded by plastic film or bags. Moreover, most of the rolls contained cardboard tubes. The designated discard code is R13. Stokvis lacks knowledge regarding the treatment applied to these recyclable residues. Additionally, Stokvis lacks a standardized process for weighing these residues, leading to inconsistencies. To address this, the mass of these residues was measured over five days and is presented in Table 3.

Table 3 - Mass of the plastic and cardboard residues and their Carbon Footprint

Material	Mass (kg/day)	CFP (kg CO_2 eq/day)
Cardboard	330	273.52
Plastic film	14	43.62
Plastic rigid	8	24.93

Specialised recycling companies already purchase cardboard, plastic film, and plastic bag residues. Stokvis was therefore losing money by not selling these residues. But, for that, it was necessary to separate the recycled and non-recycle materials. In Stokvis, this separation was not standardized, and it was not strictly conducted. Although containers were available for workers to dispose of cardboard and plastics, workers occasionally mixed recyclable and non-recyclable materials (Figure 31), discarded with the residues resulting directly from production.

Figure 31 - Mix of recycled and non-recycle materials

4.4.4 Accumulation of residues on the floor

Another issue had been identified. As the worker removed the pieces from the equipment, the residues accumulated on the floor, as shown in Figure 32. Again, this posed a safety risk to the worker as it created an obstacle on the floor in case of an emergency.

Figure 32 - Accumulation of residues on the floor

Moreover, it was wasteful because the worker frequently stopped the equipment to clean the residues from the floor. This results in a time loss, so a multi-moment analysis was done, as evidenced by the statistical analysis in Appendix I. On average, the equipment stopped for 33 seconds every 24 minutes. It is important to note that the interval between equipment stops for cleaning floor residues can vary significantly based on several factors. These factors include the material's type, thickness or density, the individual pieces being processed, and even the efficiency or technique of the worker operating the equipment. Materials with higher thickness or density generally result in more residue buildup, which may require more frequent stops for cleaning.

Similarly, certain pieces may generate more residue than others, affecting the frequency of equipment stops. Additionally, the proficiency and approach of the worker operating the equipment can impact the frequency of stops. These variations in stoppage frequency have associated costs for the company, which are represented in Table 4.

Table 4 - Labour and Equipment cost per stop of 33 seconds to remove the residues from the floor.

Labour and Equipment	**Cost** (€/stop of 33 s)	**Total (Labour plus Equipment costs)** (€/change/roll)
Labour (per worker)	0.13	-
Equipment 1, 2 or 3 (Fixed head equipment)	0.17	1 worker: 0.30 2 workers: 0.43
Equipment 4 or 5 (Rotate head equipment)	0.18	1 worker: 0.31 2 workers: 0.44
Equipment 6 (Strips equipment)	0.18	1 worker: 0.31

4.4.5 Summary of the identified problems

Considering the issues discussed in the critical analysis, Table 5 identifies the problem, lists its primary consequences, and outlines the associated Lean waste.

Table 5 - Identification of the problems, their primary consequences, and the associated Lean waste

Problem	Consequence	Lean – Green waste
High material consumption	- More parts and raw materials were consumed per unit of production; - The company was less environmentally sustainable; - More labour and equipment costs due to rolls change - Unnecessary products required additional raw materials and energy consumption during manufacturing; - Extra materials results in emissions and waste disposal.	Overproduction Over-processing Transportation Environmental wastes
Difficulty in making tool improvement	- The tool improvements were not made periodically; - There was no plan to evaluate the tools; - It was missing communication between the technical team and the line production workers; - No standardized plan for the implementation of the new tools	Over-processing
Disorganization of the management of the residues	- The company is less environmentally sustainable; - Non-optimized waste management	Transportation Motion Environmental wastes
Accumulation of residues on the floor	Production stops; Worker's unsafety; Repeat activities.	Over-processing Transportation Motion

5 Improving proposals and implementation

This chapter presents the improvement proposals to solve some of the problems identified in the previous chapter. For this, it was used the tool 5W2H represented in Table 6.

Table 6 - Improving proposals with the 5W2H tool

What		Why	How	Who	When	Where	How much?
Problem	Action						
High material consumption	Improve the material efficiency and implement a periodicity of tools evaluation	More material consumption than the necessary	Change the production tools	Margarida Marques, Engineering Team and Production workers	9/01/2023 – Future	Engineering department and Factory Floor	Price of the tools (On average, the tools cost 250 €/tool)
Difficulty in making tool improvement	Implement a periodic evaluation of the tools and standardize their implementation	Impedes the continuous improvement of processes	Periodically evaluation of the tool	Margarida Marques Engineering Team	9/01/2023 – Future	Engineering department and Factory Floor	-
Disorganization of the management of the residues	Implementation of a recycling system	Be more sustainable and have an income with the residues	Implementation of a recycle flow; Contact recycling companies	Margarida Marques, Engineering Team, Production Team and Production workers	9/01/2023 – Future	Engineering department, Production department and Factory Floor	Price of the balance (on average is 1500 €)
Accumulation of residues on the floor	Application of 5S and residues collection system for the equipment	Guarantee the worker's safety; Decrease the stops of the equipment	Construction of collection cars	Margarida Marques, Production workers	9/01/2023 – Future	Factory Floor	Price of the materials to build the collection containers

5.1 Acquisition of new tools and tools adjustments

This section encompasses proposals to mitigate high material consumption and address the challenges of improving tools. The inclusion of both these issues in a single section is due to their shared root cause: problems with tool management.

As previously indicated, the industry must implement material reduction strategies in order to foster economic and environmental sustainability. One effective approach to accomplish this objective is enhancing ME, which entails producing the same quantity of pieces while consuming fewer raw materials and generating fewer residues. In order to pursue this objective was modified the yield of various product references. This involved purchasing new tools, changing the pace or adjusting the coordinates for the tool's movement in the software's equipment 4 or 5.

A comprehensive analysis was conducted on various tools associated with multiple product references to facilitate this process. The initial selection of products focused on those with substantial sales volumes in 2022 and, simultaneously, were consuming more material than initially intended. It also evaluated the tools suggested by the equipment workers and engineering colleagues. Furthermore, other references identified randomly were assessed. Through these efforts, several references were identified as having the potential to increase the yield, minimize the residues and enhance ME.

So, to improve a tool, it was essential to consider multiple factors:

1. Blade quantity per tool: Each tool has a limited length to the blades that can incorporate. In fact, having too many blades in it can result in insufficient distribution of the pressure on every point of the tool on the material, compromising the quality of produced pieces. Therefore, balancing the length of blades and achieving the highest yield when manufacturing a tool is crucial.

2. Spacing between pieces: Providing adequate spacing between pieces is necessary to ensure the production of high-quality pieces when using bladed tools. First, the maker of the tools has difficulty producing tools with blades closer than 5 mm. Additionally, insufficient spacing or union of pieces can cause defects, particularly in curved geometries where multiple blades from various directions converge to one point. However, pieces with edges can be joined, allowing them to share a blade. Figure 33 is an example of these two cases.

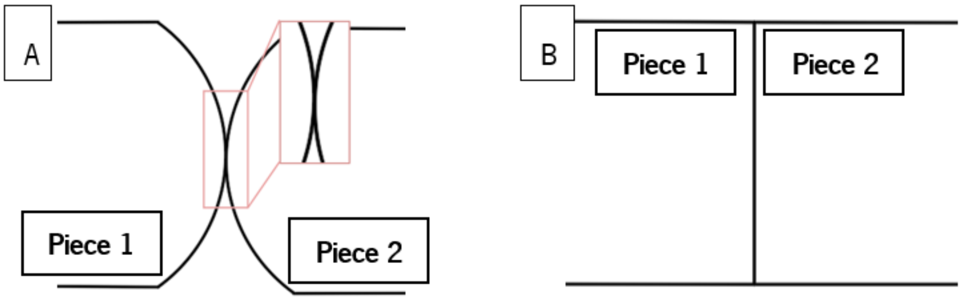


Figure 33 - Space between blades: A) Curved geometries; B) Geometries with edges

3. Material characteristics: The choice of material is also important as it can affect the tool's performance. Materials with greater thickness often require more spacing between pieces, resulting in fewer pieces per tool. On average, the recommended minimum spacing between pieces ranges between 5 and 10 mm, depending on the material's requirements.

4. The number of pieces per cycle: Considering the production rate is important to ensure an efficient workflow. If the number of pieces produced per cycle is too high for the equipment worker to handle, it may lead to frequent equipment stops, slowing the overall process. Striking a balance and adjusting the production rate to a manageable level helps maintain a steady workflow without unnecessary disruptions.

Considering these factors, the tool's performance, productivity, and quality of produced pieces can be improved, allowing optimal outcomes.

After identifying the potential references, two software programs, AutoCAD® (Autodesk) and Sysnest® (Sysco), were employed to conduct several studies to improve the tools' yield. When considering the software options available, both offer advantages and disadvantages for optimizing yield.

AutoCAD® was used with a manual trial-and-error approach to study and achieve the highest yield possible. The process involved conducting various studies manually without the assistance of automated tools. Figure 34 provides an example of multiple studies to improve the yield compared to the existing arrangement. This manual approach allowed for a thorough examination of different configurations and their potential impact on yield. However, it was important to note that this method could be time-consuming and labour-intensive.

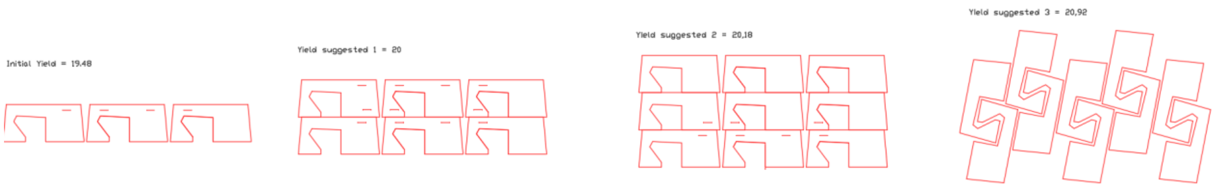


Figure 34 - Example of multiple studies to improve the yield on AutoCAD®

On the other hand, Sysnest® software was specifically designed for equipment 4 and 5. It provided an automated capability to calculate the optimal yield by generating precise coordinates for input into the equipment's program. Users only needed to input parameters such as the piece's format, roll area, minimum space between pieces, and margin width. Then, the software generated the best possible distribution of the pieces. Figure 35 illustrates an example of the software's output, displaying the piece distribution, cutting sequence, and a comprehensive report with coordinates and tool rotation.

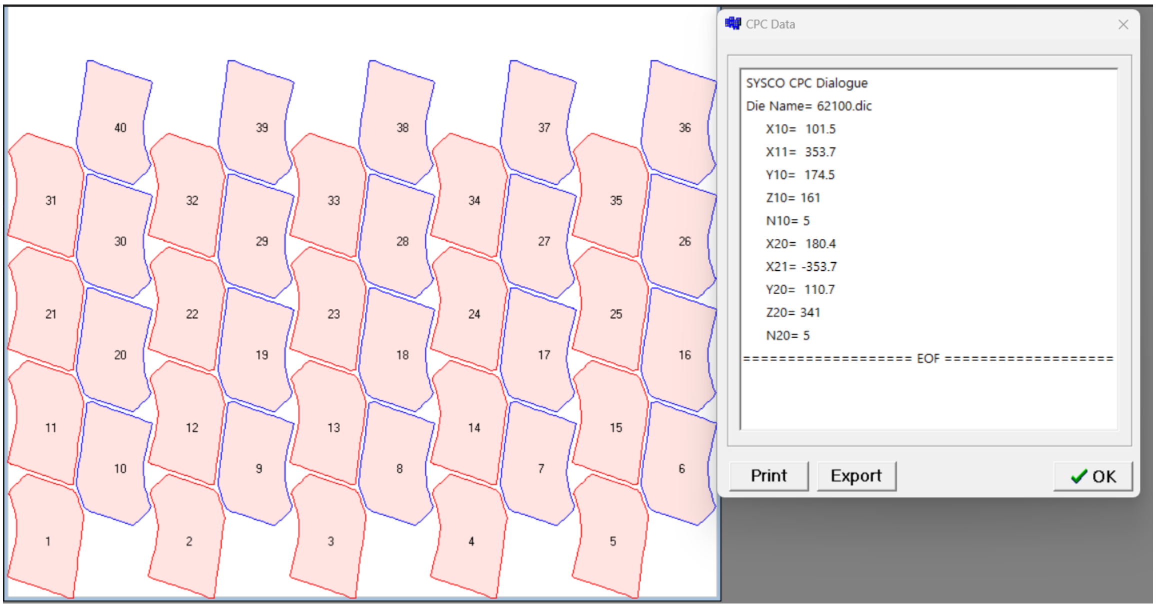


Figure 35 - Example of the Sysnest® software's output

By utilizing Sysnest, in most cases, users can maximize yield, optimize material usage, enhance productivity, and reduce waste. However, it was crucial to analyse each result from the software thoroughly. In certain cases, AutoCAD® may yield better outcomes. For instance, spacing between pieces may be unnecessary when specific parts of the piece lack curves and have straight edges or hedges. This allowed for sharing a cutting blade and could potentially improve yield. Unfortunately, the Sysnest® software cannot analyse such situations, making it important to consider alternative approaches like AutoCAD® for a comprehensive evaluation.

Additionally, equipment 4 and 5 had smaller tools than equipment 1 – 3, resulting in limitations on the size of the pieces that could be in them. Specifically, equipment 1 – 3 have tools with an area of 1.5 to

2.0 m^2, whereas equipment 4 and 5 have tools ranging from 0,64 m^2. The Sysnest® software is specifically designed for equipment 4 and 5, which means it is optimized to generate the best yield for pieces that can fit within the tool area of these equipment. Therefore, Sysnest® considers the tool size constraints and generates the most efficient nesting plans for pieces that fall within the allowed tool area, so bigger pieces cannot be analysed in this software.

In summary, both AutoCAD® and Sysnest® offer advantages and disadvantages. AutoCAD® allows for a manual trial-and-error approach, while Sysnest® provides automated calculations and streamlined processes. The choice between the two depends on the project's specific requirements and the piece's characteristics.

Every suggestion of improvement required testing to ensure its viability. The redistribution of the pieces on the material could lead to defects in the resulting pieces, as the cuts may not align as expected, affecting the overall geometry. It is crucial to consider the potential costs associated with these improvements. For instance, if a new tool needs to be purchased, a financial investment will be involved, an average of 250 € per tool. However, in some cases, the improvements may not require direct costs, such as adjusting the equipment's pace or changing the software coordinates for equipment 4 and 5.

When analysing potential savings, both the required investment and the project's longevity were considered. In certain instances, the savings achieved through the suggested improvement were minimal, making investing in a new tool not economically feasible. Careful consideration was given to determining whether the benefits outweighed the costs associated with implementing the improvement.

The decision-making process involved comprehensively evaluating each proposed improvement's potential impacts, costs, and long-term viability. This approach ensured that resources were allocated efficiently and that investments were wisely based on the projected benefits and the project's overall objectives.

During the course of this dissertation, a focus was placed on yield enhancement for 42 product references listed in Appendix II. While an extensive analysis encompassed more references, these particular 42 stood out due to their promising potential for improvements.

In equipment 1 – 5, cost savings were achieved by implementing tool modifications or adjusting the production pace. However, equipment 6 achieved savings through a different approach. It involved altering the width of each strip and manipulating the specified tolerances in the technical drawings. For example, consider reference A_14, which initially had a strip width of 0.014 m and a width tolerance of ± 0.002 m. With these specifications, it was possible to produce 33 figures across the width of the roll, resulting in a yield of 46.20 figures per square meter. By making a slight adjustment within the allowed tolerance range, the width was reduced to 0.0124 m. This modification accommodated 40 figures across the width of the roll while still adhering to the specified tolerance. As a result, the yield increased to 56 pieces per square meter. It is important to note that the Quality Department must evaluate any changes made to these pieces. In fact, this evaluation is necessary because implementing modifications requires establishing new tolerances, and the client must accept these changes. The process of evaluating and implementing these modifications is currently in progress. Equipment 6 achieved increased yield and high-cost savings by optimising strip width and manipulating tolerances. However, it was crucial to ensure that these modifications met the necessary quality standards and obtain approval from the client before fully implementing them.

5.2 Recycle system and standardized procedures

As mentioned, implementing the 6 R's system, including recycling, is crucial in today's industry. However, implementing recycling practices can be challenging in this specific industry where Stokvis operates. Hence, the initial step involved identifying the materials that could be recycled. Stokvis contacted several companies specializing in recycling and treating residues to achieve this. The communication outlined the types of scraps generated and inquired about potential valorisation materials.

Out of the 39 companies contacted, the majority (33) were based in Portugal, followed by 5 in Spain and 1 in Italy. Among these companies, 16 responded to the inquiries, and four expressed interest in valorising indirect residues from production, specifically cardboard, plastic film, and plastic bags. However, finding a buyer for the direct scraps of production proved to be challenging for several reasons:

- Mixed of different types of residues: The direct scraps of production consisted of various residues mixed. This made finding a buyer who could handle and process such a mixture difficult.
- The low mass of each type of residue: The individual mass of each residue in the scraps was relatively low. This factor made it less economically viable for potential buyers to handle and transport these small amounts of each material.

- Presence of adhesive in some scraps: Certain scraps contained adhesive, which further complicated the process of finding a buyer. Adhesive residues can impact the quality and usability of recycled materials, making them less attractive to potential buyers.

These reasons contributed to the challenges in finding buyers for the direct production scraps. However, the interest expressed by some companies in valorising the indirect residues indicates potential opportunities for recycling certain materials and having their certification of commitment to recycling. Exploring further options and potential collaborations with these interested companies could be a promising avenue to address the challenges encountered with direct scraps.

The valorisation of the indirect residues from the four companies that answered is presented in Table 7.

Table 7 - Offers of valorisation of the indirect residues.

Company	**Cost of transport** (€/ transport)	**Valorisation** (€ / ton)		
		Cardboard	**Plastic film**	**Plastic Rigid**
1	30	40	100	50
2	Stokvis in charge of the transport to Santa Maria Feira	55	200	-
3	95	70	170	-
4	100	25	127	-

Two factors must be considered when evaluating which company offers the best deal for valorising residues. Firstly, the accumulation duration is required for the residues to become valuable. Secondly, the volume of compressed residues and the time it takes to fill a transportation container should be considered to optimize transportation efficiency.

Figure 36 presents a graphical representation that compares the valorisation of residues based on the number of days they are stored before being collected. The x-axis represents the number of days between the accumulation of residues and their collection, while the y-axis represents the values of the valorised residues by the different companies. By analysing the graphic, it is possible to observe the trend of valorisation over time. The value of the residues increases as the number of days between accumulation and collection increases. This suggests that the longer the residues are stored, the higher their potential value. The graph allows for a visual comparison of the valorisation rates among different companies. It provides insights into which company offers a more favourable valorisation outcome based on the accumulation duration. This information can be used to make informed decisions regarding the best approach to valorise the residues and maximize their value.

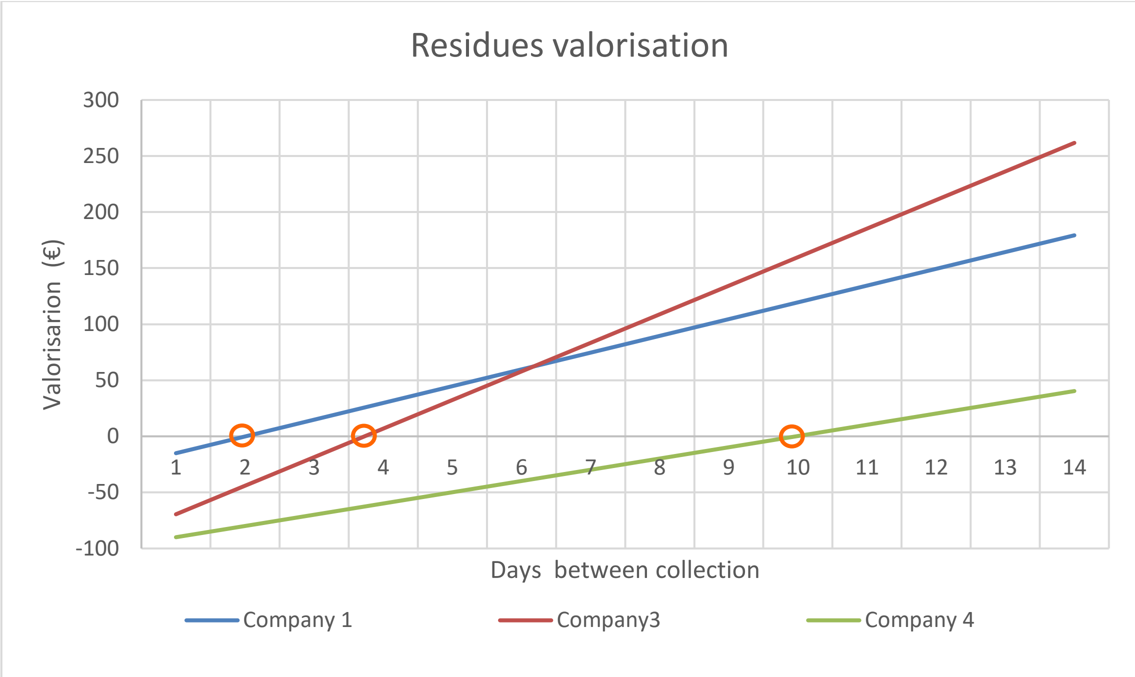


Figure 36 - Comparison of the selected companies on the residues valorisation

With company 1, Stokvis generates profit after storing the residues for 3 days. In contrast, company 3 proves profitable on the 4th day, while company 4 requires 11 days. Analysing the graph, it becomes evident that company 4 is not worth considering compared to the other two options. Company 3 is viable only if Stokvis can store the residues for more than seven working days. However, the availability of space to accumulate the residues is not the sole determining factor in selecting the best proposal. The volume of the transport container, which is 33 m^3, also plays a significant role.

However, the possible stored period requires further investigation as the residues will be compacted, necessitating an evaluation of the volume they occupy when compressed, how many days they can be stored and how many residues are necessary to achieve the full capacity of the transport container.

Unfortunately, during the dissertation period, Stokvis faced complications with their compactors. One of the compactors was inoperative, while the other was consistently occupied with managing general production residues. As a consequence, the study had to be delayed. Figure 37 depicts the current and future placements of the compactors, strategically planned to enhance the efficiency of managing all types of residues within a unified area.

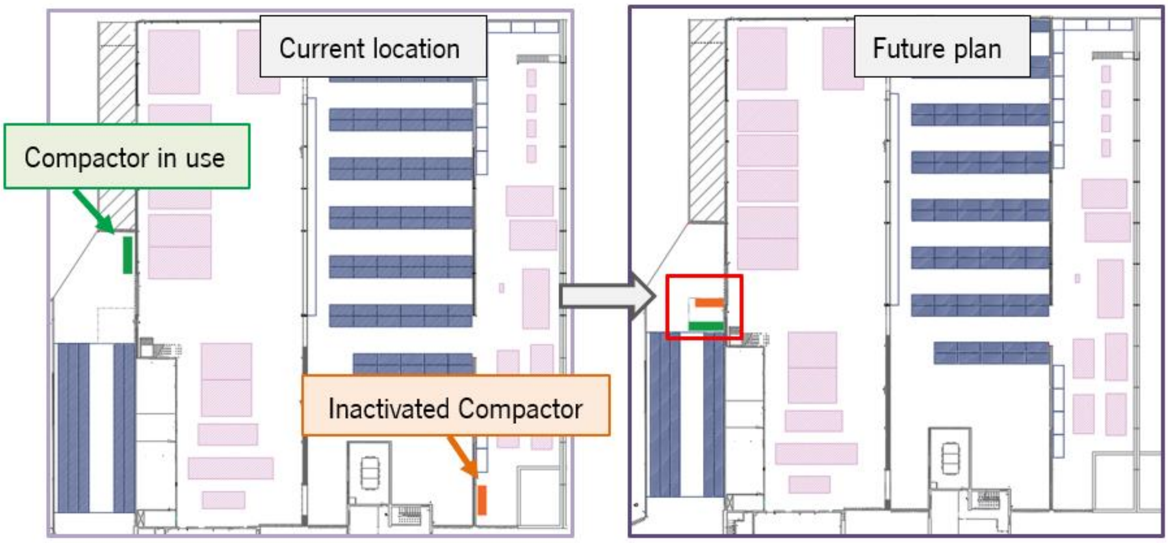


Figure 37 - Current and future placements of the compactors

To ensure standardization of the work, a collection procedure was established, outlining the valorized and recycled materials. Figure 38 provides a representation of the collection procedures. Within each area, containers are present to facilitate the separation of recyclable materials.

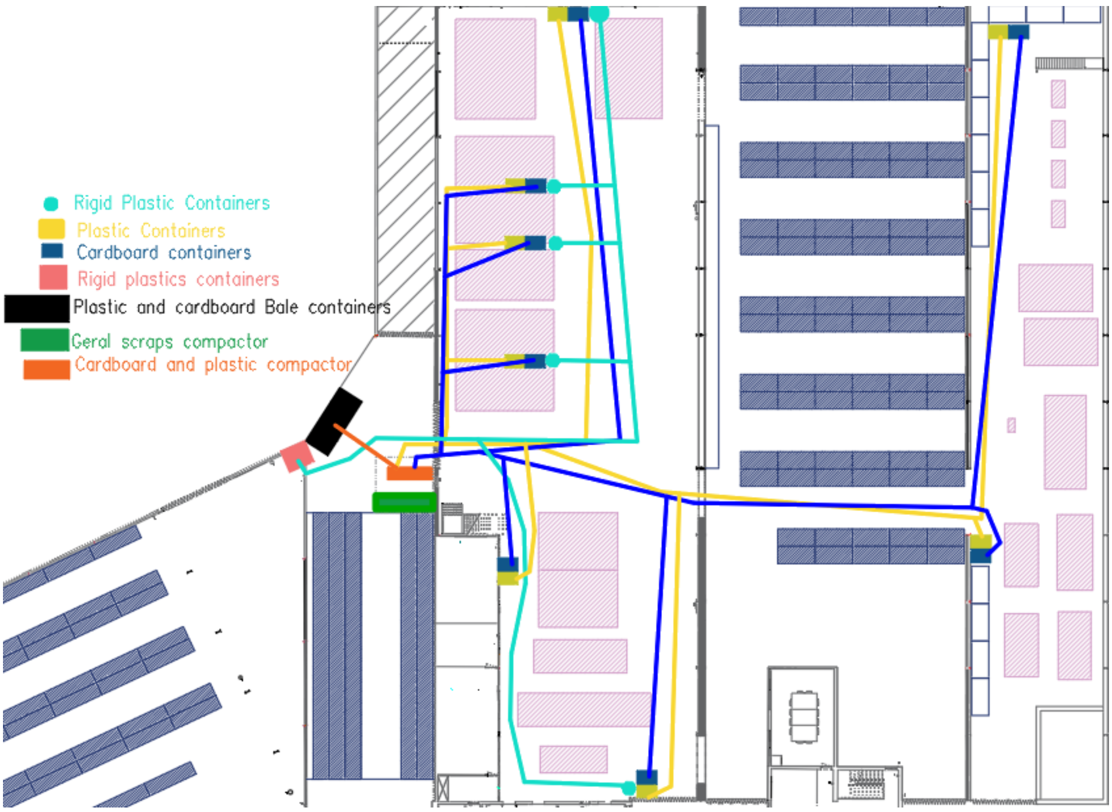


Figure 38 - Spaghetti diagram of the collection procedures of the recycled materials

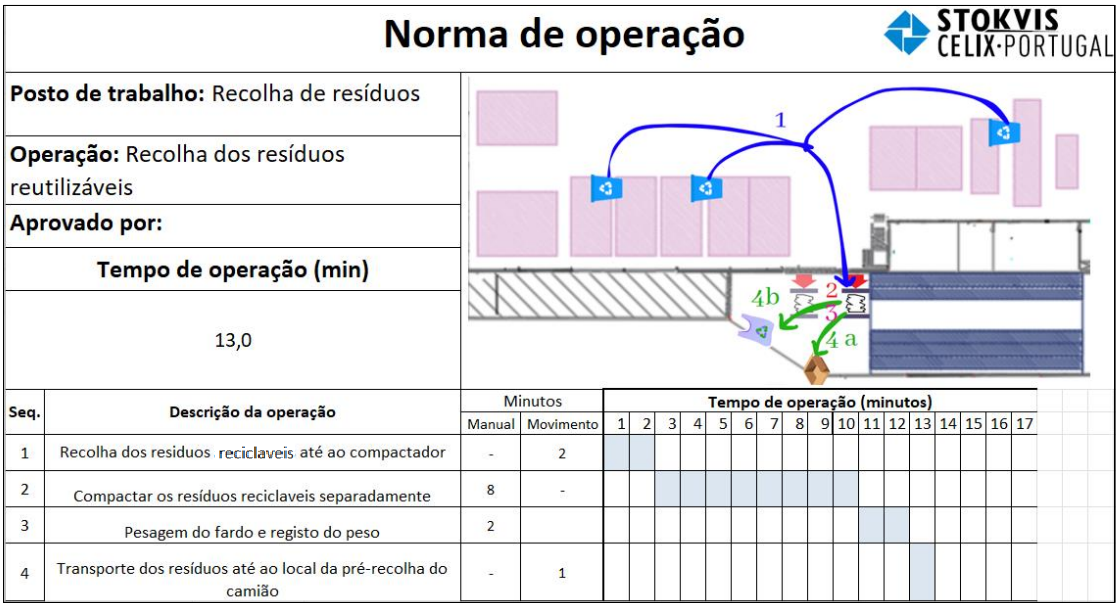
There are separate containers for rigid plastic, plastic bags and cardboard, as recycling companies require materials to be sorted by type. Figure 39 highlights the different types of recyclable plastics in orange, cardboard in blue, and rigid plastics in green. Therefore, bales containing only plastic and bales containing only cardboard are necessary. Rigid plastic, conversely, does not need to be compressed, it can be stored in bags.

Figure 39 - Identification of all the recyclable materials

Once the materials have been properly separated and baled, they can be stored together since they will be collected as a combined unit. This approach streamlines the collection process and ensures efficient handling of recycled materials.

To effectively manage the volume of generated residues and monitor their valorisation, Stokvis should consider implementing a system for volume control. A tool essential to scale the weight of the generated residues. It was proposed to Stokvis to buy a balance that could accurately measure the mass of each bale of residues. Establishing a process where each bale is carefully measured and documented was crucial. This practice should ensure precise control over the valorisation of the residues. By annotating the mass of each bale, Stokvis could track the quantity of materials being valorised and accurately assess the economic benefits obtained from their recycling efforts.

In order to ensure a consistent work process, it is essential to create a document that outlines all the necessary steps that the worker must follow. This document is represented in Figure 40 and was written in Portuguese as it was tailored for use in production. By following these steps, workers could ensure that their work was standardized.



Norma de operação STOKVIS CELIX·PORTUGAL

Posto de trabalho: Recolha de resíduos

Operação: Recolha dos resíduos reutilizáveis

Aprovado por:

Tempo de operação (min)

13,0

Seq.	Descrição da operação	Minutos		Tempo de operação (minutos)																
		Manual	Movimento	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Recolha dos residuos reciclaveis até ao compactador	-	2																	
2	Compactar os resíduos reciclaveis separadamente	8	-																	
3	Pesagem do fardo e registo do peso	2																		
4	Transporte dos resíduos até ao local da pré-recolha do camião	-	1																	

Figure 40 - Standardization worksheet of the recyclable materials

The standardized procedure included several key components to ensure clarity and consistency. It begins with describing the specific workstation where the operation occurs, followed by a comprehensive explanation. The document also specified the responsible party for creating the document, ensuring accountability. Furthermore, the expected time required to complete the activity was clearly stated, providing a guideline for efficiency. A detailed description of the activities involved in the operation was included, allowing workers to follow a step-by-step guide, which in this case was very simple, including only four steps, represented in the Figure above.

Additionally, the document outlines each activity's anticipated time, helping establish realistic timelines. Implementing standardized work procedures through clear and comprehensive documents can significantly improve communication and coordination between departments and the factory floor. This promotes a more efficient and streamlined workflow, reducing errors and fostering a more cohesive work environment.

5.3 Application of 5S and residues collection system for the equipment

The accumulated residues on the floor posed safety hazards and resulted in frequent equipment stoppages. To address this issue, implementing the 5S methodology was deemed necessary, with a particular focus on the areas where the problem predominantly occurred, on equipment 1 – 5. In this case, the core principles of the 5S methodology that needed to be applied were Seiso (Cleanliness), Seiketsu (Standardization), and Shitsuke (Discipline). Additionally, considering the supplementary S's advocated by U.S. companies, employee safety measures were incorporated into the implementation process.

Therefore, it was important to develop a solution that would enable the direct collection of materials from the residues and facilitate their seamless transfer to the compactor. This would eliminate the need for workers to interrupt equipment operations, collect residues from the floor, and manually deposit them into nearby containers. Ideally, the containers would only be removed when full and have two containers per equipment to facilitate an immediate switch and minimise time loss.

Consequently, a prototype of containers was conceived to accommodate the specific requirements of the equipment. Initially, this was achieved through the utilization of SolidWorks® software (SolidWorks), enabling the creation of virtual prototypes. Subsequently, physical prototypes were fabricated for one of the equipment and tested.

Ideally, it would be advantageous that the containers could be universally fitted beneath all equipment, for not having a lot of different containers. However, due to the varying formats and configurations of the equipment, it was necessary to adapt the container design to each individual equipment. This decision ensured that the containers could effectively utilize the maximum capacity available for each equipment. The detailed design plans for the prototypes are visually presented in Figure 41, representing the different equipment (1 – 3, 4 and 5), the container, and the corresponding assembly.

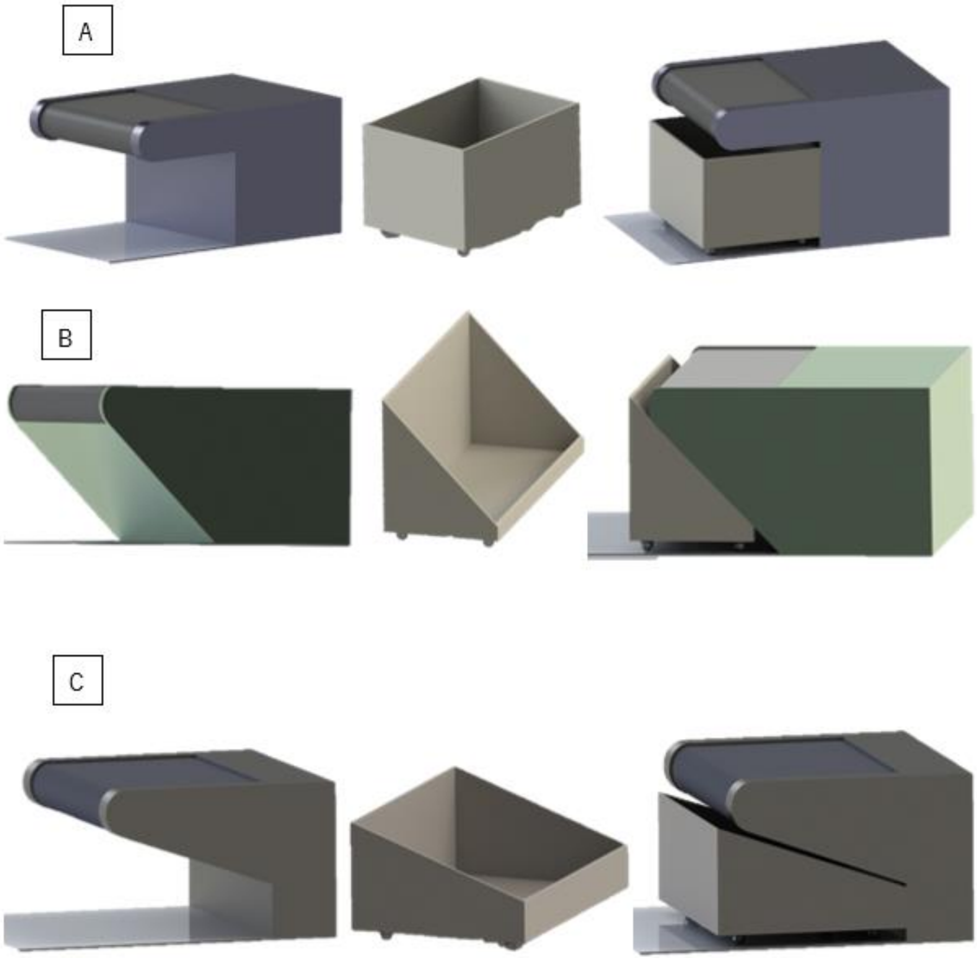


Figure 41 - Detailed design plans for the prototypes, where is represented the equipment, the collection containers and both simultaneous for equipment 1 - 3 (A), equipment 4 (B) and equipment 5 (C)

To ensure practicality and avoid operational disruptions, the containers were specifically designed to be inserted from the lateral side of the equipment. This approach was chosen to accommodate supporting tables in specific equipment if necessary. Introducing the containers from the front would require the cumbersome relocation of these tables, rendering it impractical for efficient operations.

Two containers were constructed as prototypes for equipment 1 – 3, allowing for easy switching when one container becomes full. The containers were built using metal tubes and lined with cardboard, as Figure 42 depicts.

Figure 42 - Collection container prototype to the equipment 1 - 3

Afterwards, it became essential to conduct trials on the equipment to evaluate the time required for switching when the containers reached their maximum capacity. The goal was to determine the frequency at which these switches would need to occur. Figure 43 compares the equipment's performance without and with the prototype, visually representing the experimental setup.

Figure 43 – Comparison of the equipment working without and with the collection container

Introducing containers for residue management brought about positive changes for equipment workers, including eliminating manual floor cleaning and improving working conditions. However, the worker responsible for transferring residues to the compactor expressed concerns regarding the low height of the containers. Although the container was intentionally designed to fit beneath the equipment, the worker faced difficulties transferring residues from the container to the compactor due to its lower position. It should be noted that this resistance to the new system may stem from introducing an additional activity, as the movement suggested was not significantly different from what they were doing. Despite the explanations, the workers maintained their opinion regarding the difficulties faced during the transfer process. One solution suggested by these workers was constructing a ramp near the compactor to elevate the container's height. However, this option was not tested due to the planned relocation of the compactor.

Consequently, the decision to utilize the containers had been temporarily put on hold by the responsible for shifts from the factory floor until a suitable solution could be identified. The decision to put the use of the containers on hold should ideally be made by the production department, as they had the authority to make such decisions. However, in this particular situation, it appeared that some decisions were being made by the factory floor workers instead of the designated department. It was important to ensure that the decision-making process follows the established hierarchy, involving the appropriate departments in decisions that impact production efficiency and workflow.

Like it was mentioned before, it was noted that the worker used to spend 33 seconds every 24 minutes removing residues from the floor. However, after implementing the tested container system, the worker's cleaning time was reduced to just 20 seconds, including removing a full container and inserting a new one. The costs associated with each stop using the container are represented in Table 8.

Table 8 - Costs associated with each stop of 20 seconds using the container

Labour and Equipment	**Cost** (€/stop of 20 s)	**Total (Labour plus Equipment costs)** (€/change/roll)
Labour (per worker)	0.08	-
Equipment 1, 2 or 3 (Equipment with fixed head)	0.10	1 worker: 0.18 2 workers: 0.26
Equipment 4 and 5 (Equipment with rotated head)	0.11	1 worker: 0.19 2 workers: 0.27
Equipment 6 (Strips Equipment)	0.11	1 worker: 0.19

Additionally, with the implementation of the container system, there was a noticeable decrease in the frequency of stops during production. This analysis was specifically conducted for a particular product reference. Through the container system, it was determined that the worker only needed to switch containers when approximately a roll and a half of the product were consumed. This represents a significant improvement compared to the previous approach, where the worker had to clean the floor after each roll was consumed. The container system enables standardization and control of the work process, as the worker only stops the equipment when the container is full. However, determining the exact frequency of container switches proved challenging due to the diverse materials used. Different materials have varying thicknesses, ranging from 1 mm to 15 mm, influencing the time it takes for a container to reach full capacity.

Additionally, some products yield fewer residues, while others result in more residues. Despite the difficulty in precisely counting the frequency of container switches, the overall efficiency improvement and reduced equipment downtime is evident. The container system allows for better planning and optimization of resources, as the worker can focus on production without interruptions caused by frequent floor cleaning.

It was crucial to establish standardized work procedures to address the lack of communication between departments and the factory floor and increase production efficiency. In order to achieve this, the next step would involve creating two standardized documents that outline consistent procedures for the operations, one for the worker's equipment and the other for the worker that collects the residues in the compactor. Figure 44 illustrates the standardized work of the container movement on the equipment.

Norma de operação — STOKVIS CELIX·PORTUGAL

Posto de trabalho: ATOMs, Sysco e HNC40

Operação: Recolha dos resíduos da máquina

Aprovado por:

Tempo de operação (seg)

20,0

Seq.	Descrição da operação	segundos: Manual	segundos: Movimento	Tempo de operação (segundos)																						
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	Após atingir a capacidade máxima é retirado o carro de recolha de resíduos 1, de modo a ir ser descarregado	-	10																							
2	Colocar o carro de recolha 2 de baixo do tapete da máquina	-	10																							

Figure 44 - Standardization worksheet use of the containers

Figure 45 represents the standardized work of collecting the container to the compacter and delivery of it empty. It is important to note that the procedures described in these documents were documented in Portuguese and were specifically intended for implementation within the production area.

Norma de operação

STOKVIS CELIX·PORTUGAL

Posto de trabalho: Chão de fábrica	
Operação: Transporte dos resíduos para o compactador	
Aprovado por:	
Tempo de operação (min)	
6,0	

Seq.	Descrição da operação	min		Tempo de operação (min)																							
		Manual	Movimento	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
1	O contentor de recolha ao estar com a capacidade máxima é recolhido até ao compactador	-	1																								
2	Compactção do material	5																									
2 3	Devolver o contentor até à respectiva máquina	-	1																								

Figure 45 - Standardization worksheet of the collection of the containers

6 Analysis and discussion of the results

This chapter aims to present, discuss, and quantify the results obtained after implementing the suggested improvements. In this way, indicators of the performance of the situation before (As-Is) and after (To-Be) were used to quantify the impact of the improvements.

6.1 Improve Material Efficiency

In order to analyse the impacts of the proposed suggestions, in this particular case described in section 5.1, it was essential to calculate the direct savings associated with reducing material consumption. The equations utilised for this purpose are provided in Appendix III. The effects of yield changes were calculated, mainly in four key sectors:

1. Material savings: Evaluating the impact on the area and mass of material required, as well as the associated monetary implications resulting from the proposed changes.

2. Residues container savings: By increasing the yield, the factory produced more pieces per square meter, reducing residues. As previously mentioned, Stokvis Celix incurred costs for residue treatment based on the mass of residues and the number of transportations, considering a 33 m^3 volume container. Therefore, by generating fewer residues, Stokvis Celix minimized expenses associated with residue management.

3. Equipment and labour cost savings: Utilizing less raw material to produce the same number of pieces reduced the need for roll changes. Consequently, the equipment require fewer interruptions for roll replacement, resulting in cost savings in machinery and labour. On average, a roll change took approximately 3.16 minutes.

4. Carbon Footprint (CFP) saving: Reducing material consumption leads to significant CFP savings regarding the material used in the project. The company reduced its environmental impact by minimizing the need to purchase and process additional materials.

Table 9 summarizes the cumulative annual savings, while Appendix IV provides the savings for each reference project period and the savings per year for each project. These savings are calculated from May 2nd, 2023, until the End Of the Project (EOP), which changes according to the project. It is worth noting that the suggested improvements will have an impact until 2035, leading to a projected total savings of

614 351.78 € (Please note that the total values in Table 9 may slightly differ from those presented in Table 17 of Appendix IV due to rounding).

Table 9 - Sum up the savings of the yield suggested per year.

Year	Saving material				Saving containers		Saving labour and equipment (€)	Total Saving (€)	CFP saving (kg CO_2 eq)
	Rolls (un)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
2023	316	23 079.84	9 340.66	61 206.53	5.47	1 752.94	833.52	63 792.99	29 108.22
2024	461	34 508.85	13 812.68	88 311.67	8.15	2 599.07	1 226.52	92 137.26	43 044.30
2025	448	34 249.14	13 510.28	85 710.36	8.03	2 549.66	1 211.04	89 471.06	42 101.96
2026	429	33 169.04	12 422.41	84 338.39	7.54	2 363.67	1 142.04	87 844.11	38 711.82
2027	428	33 145.82	12 404.51	84 017.27	7.53	2 360.31	1 140.00	87 517.58	38 656.04
2028	328	17 535.15	7 653.41	60 938.25	4.16	1 396.26	815.28	63 149.79	23 850.23
2029	226	5 029.08	3 182.35	42 203.96	1.26	521.64	517.08	43 242.68	9 917.12
2030	164	2 511.18	2 368.43	30 789.47	0.78	368.69	356.64	31 514.80	7 380.72
2031	87	845.15	941.55	16 790.77	0.38	155.91	177.48	17 124.17	2 934.16
2032	69	751.22	758.38	13 819.08	0.34	129.56	140.76	14 089.40	2 363.34
2033	69	751.22	758.38	13 819.08	0.34	129.56	140.76	14 089.40	2 356.87
2034	50	524.33	539.38	9 853.99	0.24	91.63	102.00	10 053.02	1 681.75
2035	2	11.80	16.81	318.84	0.01	2.60	4.08	325.52	52.40
Total	**3 077**	**186 112.01**	**77 709.52**	**592 123.09**	**44.23**	**14 421.49**	**7 807.20**	**614 351.78**	**242 165.4**

Table 9 presents a breakdown of the savings achieved per year due to a change in the tool, resulting in increased yield for different projects. The savings were measured regarding material, containers, equipment, labour, total monetary savings, and the corresponding CFP savings.

Year by year, the table showcases the projected savings from 2023 until the completion of the projects. The following analysis presents the key information provided by Table 9:

1. Saving Material: The table indicates the number of rolls, area in square meters, and mass in kilograms of saved material for each year. These savings contribute to reducing costs and improving ME. The higher number of rolls saved and the reduced area and mass of material contribute to cost savings and potentially lower material waste. In total was reduced 3 077 rolls, equivalent to 186 112 m^2 and 77.7 tons of material. This has a saving of 592 123 €.

2. Saving Containers: The savings of units and monetary associated with using fewer containers are listed yearly. So, it consumed less 44.23 containers, which is the equivalent of 14 422 €. These savings resulted from improving the ME and reducing the residues.

3. Saving equipment and Labour: This column represents the monetary savings from reducing equipment and labour costs. Implementing the new tool increased efficiency and productivity, leading to cost savings. This savings resulted from the time saved in the rolls changed because less material needed means fewer rolls needed to be acquired, resulting in less material to be replaced. The consistent savings in this category indicated long-term benefits for the company, reducing operational expenses and potentially freeing up resources for other areas. So, in total it exits a cost saving of 7 807 €.

4. Total Saving: The savings were calculated by summing up the savings in materials, containers, equipment, and labour. This provided an overview of the cumulative cost benefits over the years, which is 614 351 €.

5. CFP Saving (kg CO_2 eq): The table also included the estimated reduction of the CFP, measured in CO_2 eq, from the impact of the material use of the implemented changes, which is approximately 242.3 tons of CO_2 eq. It is important to note that the company itself did not directly generate the CFP but rather as a consequence of production, as it necessitates procuring materials that contribute to the mentioned impact. The savings highlighted the environmental benefits achieved by improving the production process. The decreasing trend in emissions savings suggested that the implemented improvements had a positive environmental effect. This reduction could contribute to the company's sustainability goals and demonstrate a commitment to reducing its CFP. However, it is worth mentioning that the CFP saving in the table only accounted for the reduction in emissions resulting from the material saved. If additional factors such as electricity usage, transportation associated with the material, and other indirect parameters related to the reduction of material used were considered, the overall CFP saving would be even higher. Calculating and considering these additional savings in the future would be beneficial.

Based on the analysis, it was evident that the implemented measures have successfully generated significant savings in terms of material, container, labour and equipment, and CFP, leading to improved efficiency and cost-effectiveness for the company. These results showcase the successful improvement of the production process and highlight the company's commitment to sustainability and profitability.

The cost savings achieved through the tool change highlighted the company's improved cost-effectiveness, with a total savings of approximately 614 352 € projected throughout the projects. These environmental benefits were noteworthy, with a total reduction of 242 166 kg CO_2 eq emissions. These sustainability efforts should be aligned with a company's commitment to environmental responsibility and which could contribute to its competitive advantage in the market.

Reducing the number of rolls used saves time in the production process while still achieving the same output. This saved time creates an opportunity cost, representing the potential profit that could be generated by utilizing that time for other purposes. Table 10 presents the annual number of rolls saved, the corresponding time saved, and the opportunity cost of this time based on the sales of 2022. It is possible to evaluate the opportunity cost between time saved and the potential profitability that could be achieved by reallocating that time to more lucrative activities.

Table 10 - Opportunity Cost: Time Saved through Roll savings

Year	Rolls saved (un)	Time saved (hour)	Opportunity cost (%)
2023	316	17.20	0.444
2024	461	25.10	0.648
2025	448	24.39	0.630
2026	429	23.36	0.603
2027	428	23,30	0.602
2028	328	17.86	0.461
2029	226	12.30	0.318
2030	164	8.93	0.231
2031	87	4.74	0.122
2032	69	3.76	0.097
2033	69	3.76	0.097
2034	50	2.72	0.070
2035	2	0.11	0.003

For instance, in 2024, there is an opportunity cost of 0.648 %. By avoiding the exchange of 461 rolls, it is possible to generate an additional 0.648% in sales volume compared to the sales achieved in 2022. This implies that the time saved can be utilized more effectively, resulting in increased profitability for the company. By saving time by exchanging 461 rolls, the company is foregoing the opportunity to allocate that time (25.10 hours) towards other activities that could generate additional profit.

Appendix VI provides an overview of the CFP impacts of each project, considering both the initial yield and the suggested yield. The total CFP, in terms of material use impact, for the 42 pieces amounted to 3 834 tonnes CO_2 eq with the initial yield and 3 605 tons CO_2 eq with the suggested yield. The implementation of changes in the yield of the tools resulted in a significant reduction of 229 tons CO_2 eq, which means a decrease of 5.97 % on the CFP impact of the material consumed on these 42 projects.

This reduction in CFP signified the positive environmental impact achieved by improving the yield of the tools.

Overall, the findings underscored the success of the tool change in achieving cost savings, operational efficiency, and environmental sustainability, positioning the company for continued growth and success. Also, it demonstrated the long-term benefits and financial advantages of the implemented improvements.

The ME considers the used material and the associated residue. The change in the toll had resulted in a ME positive variation in every case, indicating increased material use performance. Table 11 presents the ME analysis results per equipment, while Appendix V is per project. The data was presented here per equipment because equipment 6 exhibits significantly higher ME values. This is because equipment 6 utilizes almost all the material and generates fewer residues than the others equipment.

Table 11 – Material efficiency analysis results per equipment

Equipment	Average of ME with the initial Y (%)	Average of ME with the suggested Y (%)	Average of Variation of ME (%)
Equipment 1, 2 or 3	59	66	7
Equipment 4	54	63	9
Equipment 5	66	78	12
Equipment 6	93	94	1

Table 11 compares the average ME values between each equipment 's initial and suggested yields. The average variation in ME was also calculated. The data shows that the suggested yield has led to increased ME across all equipment. The improvements range from 1 % to 12 %. On equipment 1, 2, and 3, the average ME with the initial yield is 59 %, which increases to 66 % with the suggested yield. This represents a positive variation of 7 %, indicating an improvement in material usage performance. On equipment 4, the average ME with the initial yield is 54 %, while it rises to 63 % with the suggested yield. The average variation of 9% indicates a significant enhancement in ME. On equipment 5, the initial yield, yields an average ME of 66 %, which improves to 78 % with the suggested yield. This indicates a substantial increase of 12 % in ME. Lastly, on equipment 6, the ME with the initial yield is 93 %, slightly increasing to 94 % with the suggested yield. The average variation of 1 % implies a minor improvement in ME for this particular equipment.

The data presented in Appendix V demonstrates the positive impact of the toll changes on ME for each project. The ME values with the suggested yield consistently outperform those with the initial yield for all projects. The ME improvement column highlights the positive impact of the tool change on ME. The values range from as low as 0.1 % to as high as 27.6 %. Projects with higher yield improvements indicate substantial enhancements in ME due to the suggested yield.

Implementing the suggested tool design has led to consistent improvements demonstrated in the equipment-wise and Project-wise analyses. This improvement aligns with sustainability objectives by optimizing material usage, reducing waste, and enhancing resource utilization. The revised tool design has led to a higher yield, enabling more products with the same amount of raw materials. This reduction in material waste has positive environmental implications, including minimized residues and a reduced environmental footprint associated with waste disposal. Additionally, the enhanced ME brings economic advantages, such as cost savings in raw material procurement, production expenses, and waste management. Ultimately, these changes reflect a sustainable approach to production, showcasing the significant impact of small design adjustments on sustainability outcomes.

6.2 Implementation of a recycling system

The communication with recycling companies revealed a higher response rate from companies based in Portugal, indicating the availability of local options for valorising residues. However, the difficulty in finding buyers for the direct scraps of production was evident due to the mixed nature of the residues, low individual mass, and adhesive in some scraps. These factors posed challenges in handling, processing, and the quality of recycled materials, making them less attractive to potential buyers.

In contrast, the interest expressed by some companies in valorising indirect residues, such as cardboard, plastic film, and plastic bags, presented a potential avenue for recycling specific materials. Exploring collaborations with these interested companies could be valuable in addressing the challenges faced with direct scraps and maximizing recycling efforts.

The offers received from companies specializing in valorising indirect residues provide valuable insights for decision-making. Factors such as transport costs and valorisation rates per ton significantly determined the most favourable options. Additionally, the graphical representation of valorisation rates over time highlighted the importance of accumulation duration for maximizing the value of residues. It becomes apparent that longer storage periods result in higher potential value, emphasizing the need for efficient storage and management of materials.

The discussion also emphasized the importance of adequately separating and sorting recyclable materials to streamline the collection process. Stokvis should establish a collection procedure with separate containers for different materials, ensuring compliance with recycling companies' requirements. This approach facilitates efficient handling and collection of the materials, contributing to overall operational efficiency.

The suggestion to implement a system for volume control, such as using a balance to measure the mass of each bale, was crucial for accurate monitoring and assessment of valorisation efforts. This data allowed Stokvis to track the quantity of valorised materials, evaluate economic benefits, and make informed decisions regarding recycling strategies.

Overall, the data and analysis presented highlight the complexities and potential solutions in implementing recycling practices in Stokvis' industry. By addressing the challenges, leveraging opportunities, and implementing appropriate control measures, Stokvis enhanced sustainability efforts, optimized resource utilization, and contributed to a greener future.

In fact, the recycling of cardboard and plastics has CFP savings associated with the process. Both processes have CFP savings due to several factors:

1. Energy Savings:

    a. Recycling cardboard saved energy compared to producing new cardboard from virgin materials. Collecting, sorting and processing recycled cardboard required less energy than manufacturing cardboard from raw materials. According to the EPA (2019), recycling one ton of cardboard saves approximately 390 kWh of energy. In Stokvis, about 330 kg of cardboard was produced per working day, equivalent to 85.8 tons annually (considering 260 working days), saving 33 462 kWh of energy.

    b. Recycling plastic also saves energy. According to the EPA (2019), recycling one ton of plastic can save approximately 5 774 kWh of energy. With 24 kg of plastic per working day for 260 days per year, 6.24 tons of plastic is produced annually, saving 36 029 kWh of energy.

2. Carbon Emission Reduction:

    a. By recycling cardboard, the carbon emissions associated with its production were significantly reduced. According to Turner et al. (2015), it was estimated that recycling the quantities of cardboard mentioned earlier resulted in a CFP savings of approximately 39 468 kg CO_2 eq per year.

b. Similarly, recycling the quantities of plastic mentioned in the project led to a CFP savings of approximately 6 364.80 kg CO_2 eq per year.

3. Resource Conservation:

   a. Recycling cardboard helped to conserve valuable natural resources. Using recycled cardboard instead of virgin materials means fewer trees must be harvested, reducing deforestation and preserving forest ecosystems. Additionally, recycling cardboard reduces water consumption since producing recycled cardboard requires less water than manufacturing cardboard from raw materials. According to the Department of Environmental Protection of Montgomery County, this recycling saved 502 trees and 573 litters of water (Department of Environmental Protection of Montgomery County, Maryland)

   b. Recycling plastic conserves valuable resources such as petroleum and natural gas. By using recycled plastic, the demand for virgin materials is reduced, resulting in the conservation of these limited resources. Additionally, recycling plastic helps to alleviate the strain on ecosystems and habitats associated with extracting and processing fossil fuels. According to the Department of Environmental Protection of Montgomery County, this recycling avoided 961 litters of oil used (Department of Environmental Protection of Montgomery County Maryland)

Furthermore, Stokvis had implemented a code for the operation of code residues, currently labelled as R13, which does not guarantee the clients that these residues generated in Stokvis are recycled. To enhance the recycling efforts and improve client negotiations, Stokvis can change the code to R5, which stands for "*Reciclagem/recuperação de outras matérias inorgânicas*". This change benefited client relations and contributed to Stokvis' goal of achieving ISO 14001 certification, demonstrating its commitment to environmental management.

6.3 Implementation of a collection system of the residues in the equipment

Implementing the container system in the factory yielded positive results in various aspects.

Firstly, removing residues from the floor significantly reduced the cleaning time required. Before the implementation, the worker spent an average of 33 seconds every 24 minutes on this task. However, with the container system in place, the cleaning time had been reduced to just 20 seconds, including removing a full container and inserting a new one. This time saving allows workers to allocate more time to productive tasks, enhancing overall efficiency.

Moreover, the container system resulted in a noticeable decrease in equipment stoppages during production. For example, for one specific product previously described, the worker had to clean the floor after each roll of the product was consumed, causing frequent interruptions. However, with the container system, the worker only needed to switch containers when approximately a roll and a half of the product was consumed. This improvement in the frequency of stops reduced equipment downtime and increased production efficiency.

The container introduction also improved working conditions for equipment workers. Manual floor cleaning had been eliminated, which poses safety hazards and physical strain. This elimination created a safer and more comfortable work environment, enhancing employee well-being and satisfaction.

In terms of cost-effectiveness, implementing the container system proved to be beneficial. Cost comparison between the equipment and human costs with and without containers revealed a cost reduction per stop, as represented in Table 12.

Table 12 - Cost comparison between equipment and human costs with and without containers

Labour and Equipment	**Without container** Stop of 33 s		**With container** Stop of 20 s		**Saving**	
	Cost per stop (€/stop)	**Total - Labour plus Equipment** (€/stop)	**Cost per stop** (€/stop)	**Total - Labour plus Equipment** (€/stop)	**Saving per stop** (€/stop)	**Total savings - Labour plus Equipment** (€/stop)
Labour/worker	0.13	-	0.08	-	0.05	-
Equipment 1, 2 or 3	0.17	1 worker: 0.30 2 workers: 0.43	0.10	1 worker: 0.18 2 workers: 0.26	0.07	1 worker: 0.12 2 workers: 0.17
Equipment 4 or 5	0.18	1 worker: 0.31 2 workers: 0.44	0.11	1 worker: 0.19 2 workers: 0.27	0.07	1 worker: 0.12 2 workers: 0.17
Equipment 6	0.18	1 worker: 0.31	0.11	1 worker: 0.19	0.07	1 worker: 0.12

The provided data underscores the substantial impact that the use of containers can have on total savings in the labour and equipment domain. By significantly reducing stop times, the introduction of containers results in notable cost reductions per stop. The highest savings are observed with equipment 1 – 5, where implementing containers can lead to total savings of 0.12 € to 0.17 € per stop, depending on the number of workers involved. For equipment 6, the savings amount is 0.12 € per stop. These seemingly small savings per stop accumulate over time, translating into substantial total savings when considering the frequency of stops throughout an operation's lifecycle. By prioritizing the utilization of containers, companies can achieve significant cost efficiencies, optimizing their resources and ultimately improving their bottom line.

Overall, the container implementation yielded positive outcomes, including reduced cleaning time, decreased equipment stoppages, improved working conditions, and cost-effectiveness. The system aligns with the principles of the 5S methodology, particularly cleanliness (Seiso) and standardization (Seiketsu).

The passage mentions that despite the positive changes brought about by the container system, the workers responsible for transferring residues to the compactor expressed concerns regarding the low height of the containers. Due to its lower position, the workers found it difficult to transfer residues from the container to the compactor. It is important to analyse the worker's resistance and concerns to understand the potential impact on the overall effectiveness of the container system. The worker's difficulty can lead to inefficiencies. In this case, the suggested solution from the workers was to construct a ramp near the compactor to elevate the container's height. However, this option was not tested due to the planned relocation of the compactor. It is essential to consider the worker's feedback and suggestions, as they have direct experience with the tasks and can provide valuable insights into practical solutions. The resistance to using the containers and the worker's concerns highlight the importance of involving workers in decision-making and considering their perspectives. It is crucial to address their concerns and find practical solutions to ensure smooth implementation and acceptance of the new system.

Additionally, it is crucial to ensure effective communication and alignment between departments and the factory floor. The decision to put the use of the containers on hold was made by the factory floor workers instead of the designated production department. It is important to involve the appropriate departments in decision-making processes that impact production efficiency and workflow to ensure a smooth and well-coordinated implementation of initiatives like the container system.

Locating companies specializing in recycling the scraps produced in Stokvis has been challenging. However, this problem should be addressed in the future. It would be beneficial to find companies that recycle these residues. And if a recycling company becomes interested in these materials in the future, implementing these containers to segregate the residues by their respective raw materials would be an effective solution. By dedicating one container to each specific material, creating bales consisting solely of a single material type becomes feasible. This approach streamlines the recycling process by simplifying identification and separation, enhancing efficiency, and potentially promoting more sustainable practices in production.

6.4 Balance ScoreCard

During the research project, the Lean - Green measures implemented at Stokvis significantly impacted business performance. A BSC analysis was conducted to analyse these measures' impact, focusing on the internal processes' perspective represented in Figure 46.

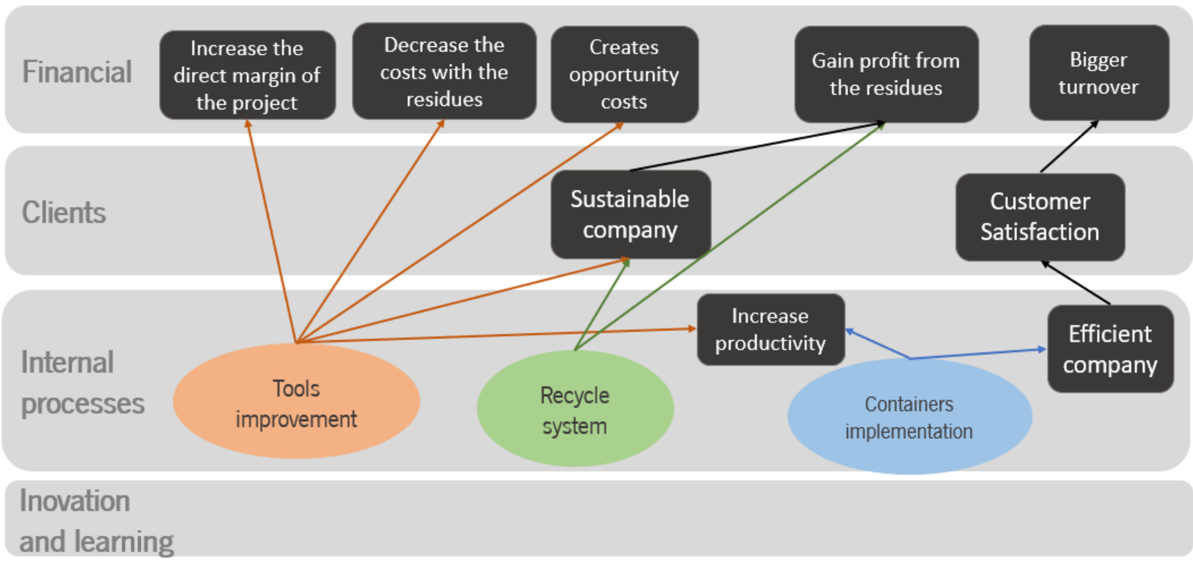


Figure 46 - Balance ScoreCard of the research project developed

Firstly, improving the yield of production tools resulted in several financial benefits. It increased the direct margin of the project, reduced costs associated with waste disposal, created opportunities for cost savings, and improved overall productivity. From a client's perspective, Stokvis conveyed a strong message of continuous improvement to promote sustainability.

Secondly, implementing a recycling system had financial and client-related impacts. Financially, the recycling system allowed for profit generation by utilising residues. From a client's perspective, it demonstrated Stokvis as a more environmentally responsible and sustainable company.

Lastly, the introduction of containers on machines had financial implications through increased process productivity, minimized production stops, and the creation of opportunity costs. From a client's perspective, it portrayed Stokvis as an organized and efficient company, as the absence of residues on the factory floor showcased a clean and well-maintained environment.

It is worth noting that while these measures primarily affected the financial and client perspectives within the BSC, their impact on the learning and innovation aspect was not prominent in this particular project.

Overall, integrating Lean - Green measures into the Balanced Scorecard framework at Stokvis resulted in positive outcomes for business performance, demonstrating the value of sustainability initiatives in driving financial gains and enhancing the company's reputation among clients.

6.5 Summary of the results

The main objective of this section is to summarize the key findings and outcomes of the research project quantitatively.

Table 13 - Summary of results obtained

Proposals	Results	Gains
Tools improvement	- Increase the material efficiency - Increase the direct margin of the project - Decrease the costs of the residue's treatment - More sustainable production processes	- Monetary material savings = 592 123.09 € - Monetary residues containers savings =14 421.49 € - Monetary equipment and labour savings =7 807.20 € Total savings = 614 351.78 € - Carbon footprint saving = 242 165.40 kg CO_2 eq
Recycle system	- More sustainable company - Gain profit from the residues	- The monetary profit will depend on which proposal is chosen - Recycling offers the following environmental savings: - Energy = 69 491 kWh/year - Carbon footprint = 45 862 kg CO_2 eq
Containers implementation	- Increase productivity - Safety of equipment workers - Cleanliness of the workplace	- Decrease cleaning time from 33 to 20 seconds - Saving per stop of 0.12 to 0.17 € - Decrease the frequency of stops

7 Conclusions

In this final chapter, the conclusions of this research project and recommendations for future work are presented.

7.1 Conclusions

In conclusion, implementing Lean - Green principles at Stokvis Celix has significantly improved the company's economic and environmental efficiency. By addressing key issues such as high material consumption, limited improvements in production tools, waste management disorganization, and worker safety, Stokvis Celix has achieved significant results.

By analysing 42 product tools, the company improved their efficiency, resulting in total savings of 614 351.78 €. These savings were distributed across various areas, with 592 124 € saved on material consumption, 14 422 € on residues containers, and 7 808 € on equipment and labour. In addition to the monetary benefits, these improvements also led to a substantial reduction in carbon footprint, amounting to 242 166 kg CO_2 eq.

Implementing recycling practices has been identified as one of the first steps towards sustainability at Stokvis Celix. While challenges were encountered in finding buyers for direct production scraps, opportunities were identified for recycling and valorising indirect residues such as cardboard, plastic film, and plastic bags. Several purchase proposals for the residues were received, emphasizing the importance of effective storage practices in determining the most profitable option.

Furthermore, introducing a residues container system on the equipment, implemented as a part of the 5S methodology, positively impacted the production process, contributing to the safety of equipment workers and the cleanliness of the workplace. This system significantly reduced cleaning time from 33 to 20 seconds, minimized equipment stoppages, and improved working conditions. Additionally, it has proven cost-effective, optimizing resource utilisation, and reducing costs per stop by 0.12 to 0.17 €.

Overall, by implementing Lean - Green principles, Stokvis Celix can successfully reduce material waste, increase yield, achieve substantial cost savings, and increase productivity. Through a continuous pursuit of improvement and a commitment to a Lean - Green mindset, Stokvis Celix can position itself as a more efficient, cost-effective, and environmentally conscious organization within the industry. The combination of significant cost savings, reduced carbon footprint, and enhancements in worker safety and efficiency highlight the success and positive impact of Stokvis Celix. The Lean - Green proposals resulted in improving business performance.

7.2 Future work

In order to continue improving operations and maximizing efficiency, these are the recommendations to Stokvis Celix for future work:

- Applying a system for predictive maintenance is recommended for the condition and performance of tools. This can be achieved by establishing a schedule or assigning a specialized individual who evaluates the production tools regularly.
- Sysnest® Software should be used more regularly and emphasized as a standard practice.
- The residues produced by each product should be calculated when the project is gained. Through this calculation is possible to guarantee control of waste production.
- Improving communication between the production department and workers on the factory floor is another crucial aspect. By establishing better communication channels, the company can avoid losses, enhance efficiency, and effectively implement suggested improvements. Regular meetings, feedback sessions, and clear communication protocols can facilitate collaboration and problem-solving.
- Stokvis Celix should also actively seek companies that value direct production residues. The company can optimize resource utilization, reduce waste, and potentially generate additional revenue streams by finding suitable partners. And also, by incentive, recycling the main residues produced will transform Stokvis into a more attractive company.
- Stokvis should also invest in a weighing system to ensure accurate residue measurement, particularly when dealing with recyclable materials. This will enable proper measurement, monitoring, and assessment of recycling efforts, providing valuable data for decision-making and evaluation of economic benefits.

By implementing these future work recommendations, Stokvis Celix can further enhance its operations, reduce waste, optimize resource utilization, improve communication, and reinforce its commitment to environmental responsibility and economic sustainability.

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Annex

Annex I - GHG conversion factors established by the UK Government

Table 14 represents the GHG conversion factors established by the UK Government.

Table 14 - UK Government GHG Conversion Factors
(DEFRA, 2022)

Level 1	Level 2	Level 3	Column Text	UOM	GHG/Unit	GHG Conversion Factor 2022
Material use	Construction	Aggregates	Primary material production	tonnes	kg CO2e	7.75102
Material use	Construction	Aggregates	Re-used	tonnes	kg CO2e	2.21000
Material use	Construction	Aggregates	Closed-loop source	tonnes	kg CO2e	3.19471
Material use	Construction	Average construction	Primary material production	tonnes	kg CO2e	80.33777
Material use	Construction	Asbestos	Primary material production	tonnes	kg CO2e	27.00000
Material use	Construction	Asphalt	Primary material production	tonnes	kg CO2e	39.21249
Material use	Construction	Asphalt	Re-used	tonnes	kg CO2e	1.73826
Material use	Construction	Asphalt	Closed-loop source	tonnes	kg CO2e	28.65471
Material use	Construction	Bricks	Primary material production	tonnes	kg CO2e	241.75102
Material use	Construction	Concrete	Primary material production	tonnes	kg CO2e	131.75102
Material use	Construction	Concrete	Closed-loop source	tonnes	kg CO2e	3.19471
Material use	Construction	Insulation	Primary material production	tonnes	kg CO2e	1861.75102
Material use	Construction	Insulation	Closed-loop source	tonnes	kg CO2e	1852.08089
Material use	Construction	Metals	Primary material production	tonnes	kg CO2e	4018.00295
Material use	Construction	Metals	Closed-loop source	tonnes	kg CO2e	1571.27037
Material use	Construction	Soils	Closed-loop source	tonnes	kg CO2e	0.98471
Material use	Construction	Mineral oil	Primary material production	tonnes	kg CO2e	1401.00000
Material use	Construction	Mineral oil	Closed-loop source	tonnes	kg CO2e	676.00000
Material use	Construction	Plasterboard	Primary material production	tonnes	kg CO2e	120.05000
Material use	Construction	Plasterboard	Closed-loop source	tonnes	kg CO2e	32.17000
Material use	Construction	Tyres	Primary material production	tonnes	kg CO2e	3335.57190
Material use	Construction	Tyres	Re-used	tonnes	kg CO2e	731.21789
Material use	Construction	Wood	Primary material production	tonnes	kg CO2e	312.61178
Material use	Construction	Wood	Re-used	tonnes	kg CO2e	38.54288
Material use	Construction	Wood	Closed-loop source	tonnes	kg CO2e	112.96968
Material use	Other	Glass	Primary material production	tonnes	kg CO2e	1402.76667

Level 1	Level 2	Level 3	Column Text	UOM	GHG/Unit	GHG Conversion Factor 2022
Material use	Other	Glass	Closed-loop source	tonnes	kg CO2e	823.18954
Material use	Other	Clothing	Primary material production	tonnes	kg CO2e	22310.0000
Material use	Other	Clothing	Re-used	tonnes	kg CO2e	152.25000
Material use	Other	Food and drink	Primary material production	tonnes	kg CO2e	3701.40359
Material use	Organic	Compost derived from garden waste	Primary material production	tonnes	kg CO2e	112.01558
Material use	Organic	Compost derived from food and garden waste	Primary material production	tonnes	kg CO2e	114.83221
Material use	Electrical items	Electrical items - fridges and freezers	Primary material production	tonnes	kg CO2e	4363.33333
Material use	Electrical items	Electrical items - large	Primary material production	tonnes	kg CO2e	3267.00000
Material use	Electrical items	Electrical items - IT	Primary material production	tonnes	kg CO2e	24865.47556
Material use	Electrical items	Electrical items - small	Primary material production	tonnes	kg CO2e	5647.94563
Material use	Electrical items	Batteries - Alkaline	Primary material production	tonnes	kg CO2e	4633.47826
Material use	Electrical items	Batteries - Li ion	Primary material production	tonnes	kg CO2e	6308.00000
Material use	Electrical items	Batteries - NiMh	Primary material production	tonnes	kg CO2e	28380.0000
Material use	Metal	Metal: aluminium cans and foil (excl. forming)	Primary material production	tonnes	kg CO2e	9122.63640
Material use	Metal	Metal: aluminium cans and foil (excl. forming)	Closed-loop source	tonnes	kg CO2e	999.39628
Material use	Metal	Metal: mixed cans	Primary material production	tonnes	kg CO2e	5268.55640
Material use	Metal	Metal: mixed cans	Closed-loop source	tonnes	kg CO2e	1473.78996
Material use	Metal	Metal: scrap metal	Primary material production	tonnes	kg CO2e	3682.68290
Material use	Metal	Metal: scrap metal	Closed-loop source	tonnes	kg CO2e	1633.17782
Material use	Metal	Metal: steel cans	Primary material production	tonnes	kg CO2e	3100.63640
Material use	Metal	Metal: steel cans	Closed-loop source	tonnes	kg CO2e	1740.63640
Material use	Plastic	Plastics: average plastics	Primary material production	tonnes	kg CO2e	3116.29156
Material use	Plastic	Plastics: average plastics	Closed-loop source	tonnes	kg CO2e	2326.53028
Material use	Plastic	Plastics: average plastic film	Primary material production	tonnes	kg CO2e	2574.16475
Material use	Plastic	Plastics: average plastic film	Closed-loop source	tonnes	kg CO2e	1894.62863
Material use	Plastic	Plastics: average plastic rigid	Primary material production	tonnes	kg CO2e	3276.70693
Material use	Plastic	Plastics: average plastic rigid	Closed-loop source	tonnes	kg CO2e	2748.83298

Level 1	Level 2	Level 3	Column Text	UOM	GHG/Unit	GHG Conversion Factor 2022
Material use	Plastic	Plastics: HDPE (incl. forming)	Primary material production	tonnes	kg CO2e	3269.83889
Material use	Plastic	Plastics: HDPE (incl. forming)	Closed-loop source	tonnes	kg CO2e	2350.61634
Material use	Plastic	Plastics: LDPE and LLDPE (incl. forming)	Primary material production	tonnes	kg CO2e	2600.63640
Material use	Plastic	Plastics: LDPE and LLDPE (incl. forming)	Closed-loop source	tonnes	kg CO2e	1797.22268
Material use	Plastic	Plastics: PET (incl. forming)	Primary material production	tonnes	kg CO2e	4032.39250
Material use	Plastic	Plastics: PET (incl. forming)	Closed-loop source	tonnes	kg CO2e	3125.27157
Material use	Plastic	Plastics: PP (incl. forming)	Primary material production	tonnes	kg CO2e	3104.72699
Material use	Plastic	Plastics: PP (incl. forming)	Closed-loop source	tonnes	kg CO2e	2541.31327
Material use	Plastic	Plastics: PS (incl. forming)	Primary material production	tonnes	kg CO2e	3777.94890
Material use	Plastic	Plastics: PS (incl. forming)	Closed-loop source	tonnes	kg CO2e	3198.95732
Material use	Plastic	Plastics: PVC (incl. forming)	Primary material production	tonnes	kg CO2e	3413.08416
Material use	Plastic	Plastics: PVC (incl. forming)	Closed-loop source	tonnes	kg CO2e	2489.67044
Material use	Paper	Paper and board: board	Primary material production	tonnes	kg CO2e	828.86816
Material use	Paper	Paper and board: board	Closed-loop source	tonnes	kg CO2e	719.55532
Material use	Paper	Paper and board: mixed	Primary material production	tonnes	kg CO2e	884.16078
Material use	Paper	Paper and board: mixed	Closed-loop source	tonnes	kg CO2e	731.67375
Material use	Paper	Paper and board: paper	Primary material production	tonnes	kg CO2e	919.39628
Material use	Paper	Paper and board: paper	Closed-loop source	tonnes	kg CO2e	739.39628

Annex II – Codes to the Waste Disposal and Recovery Operations

This Annex presents the Waste Disposal and Recovery Operations, which is in Portuguese (Portaria n.º209/2004):

D1 – Deposição sobre o solo ou no seu interior (por exemplo, aterro sanitário, etc.).

D2 – Tratamento no solo (por exemplo, biodegradação de efluentes líquidos ou de lamas de depuração nos solos, etc.).

D3 – Injecção em profundidade (por exemplo, injecção de resíduos por bombagem em poços, cúpulas salinas ou depósitos naturais, etc.).

D4 – Lagunagem (por exemplo, descarga de resíduos líquidos ou de lamas de depuração em poços, lagos naturais ou artificiais, etc.)

D5 – Depósitos subterrâneos especialmente concebidos (por exemplo, deposição em alinhamentos de células que são seladas e isoladas umas das outras e do ambiente, etc.).

D6 – Descarga para massas de águas, com excepção dos mares e dos oceanos.

D7 – Descarga para os mares e ou oceanos, incluindo inserção nos fundos marinhos.

D8 – Tratamento biológico não especificado em qualquer outra parte do presente Anexo que produz compostos ou misturas finais que são rejeitados por meio de qualquer das operações enumeradas de D1 a D12.

D9 – Tratamento físico-químico não especificado em qualquer outra parte do presente Anexo que produz compostos ou misturas finais rejeitados por meio de qualquer das operações enumeradas de D1 a D12 (por exemplo, evaporação, secagem, calcinação, etc.).

D10 – Incineração em terra.

D11 – Incineração no mar.

D12 – Armazenagem permanente (por exemplo, armazenagem de contentores numa mina,etc.).

D13 – Mistura anterior à execução de uma das operações enumeradas de D1 a D12.

D14 – Reembalagem anterior a uma das operações enumeradas de D1 a D13.

D15 – Armazenagem enquanto se aguarda a execução de uma das operações enumeradas de D1 a D14 (com exclusão do armazenamento temporário, antes da recolha, no local onde esta é efectuada).

R1 – Utilização principal como combustível ou outros meios de produção de energia.

R2 – Recuperação/regeneração de solventes.

R3 – Reciclagem/recuperação de compostos orgânicos que não são utilizados como solventes (incluindo as operações de compostagem e outras transformações biológicas).

R4 – Reciclagem/recuperação de metais e de ligas.

R5 – Reciclagem/recuperação de outras matérias inorgânicas.

R6 – Regeneração de ácidos ou de bases.

R7 – Recuperação de produtos utilizados na luta contra a poluição.

R8 – Recuperação de componentes de catalisadores.

R9 – Refinação de óleos e outras reutilizações de óleos.

R10 – Tratamento no solo em benefício da agricultura ou para melhorar o ambiente.

R11 – Utilização de resíduos obtidos em virtude das operações enumeradas de R1 a R10.

R12 – Troca de resíduos com vista a submetê-los a uma das operações enumeradas de R1 a R11.

R13 – Acumulação de resíduos destinados a uma das operações enumeradas de R1 a R12 (com exclusão do armazenamento temporário, antes da recolha, no local onde esta é efectuada).

Appendix

Appendix I – Work Sampling Analysis

Work sampling allows for estimating the percentage of time spent on identified activities (Berenson et al., 2008). For this, random observations are made to record the activities.

To calculate the required sample size, use Equation 3.

Equation 3 - Work sampling equation (Berenson et al., 2008)

$$N = \frac{Z^2 \times p \times (1 - p)}{e^2}$$

Where:

N = Number of observations to be made

Z = Number of standard deviations associated with a given confidence level (to a level of confidence of 95 %, Z = 1.96)

p = Estimated proportion of time that the activity being measured occurs (for the equipment in the study, the productivity was 45 %)

e = Absolute error that is desired (5 %).

With these data, N = 380 were obtained, and observations were made.

In these observations, the time to change the roll, the time to remove the residues from the floor and the frequency of stops to remove the residues from the floor was determined. The descriptive statistics analysis is represented in Table 15.

Table 15 - Descriptive statistics of the time to change the roll and the time to remove the residues of the floor.

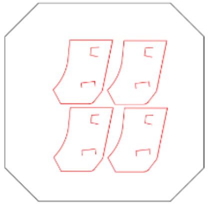
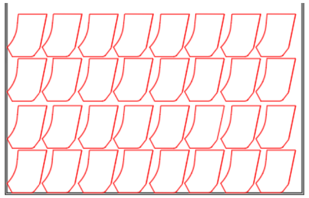
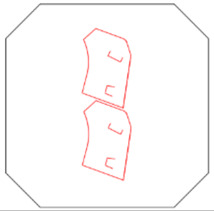
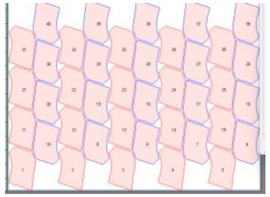
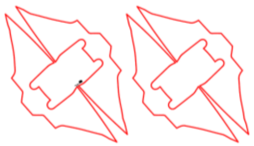
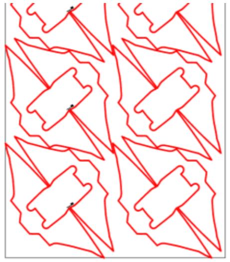
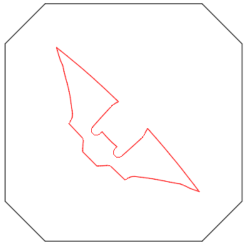
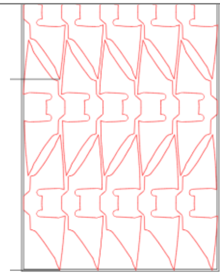
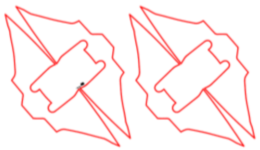
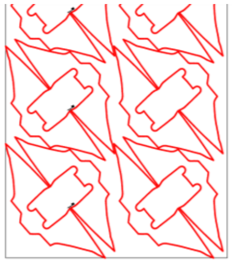
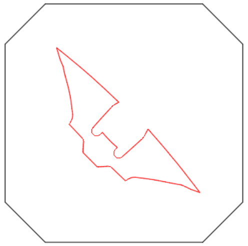
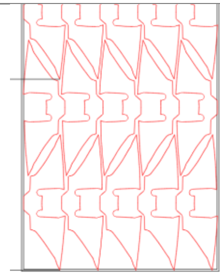
Parameters	Change roll	Remove residues from the floor	Interval between stops to remove the residues of the floor
Average	216.98 s	33.50 s	24 min
Standard error	3.93	2.92	1.38
Standard deviation	75.15	56.84	13.23
Number of observations	380	380	380

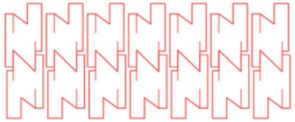
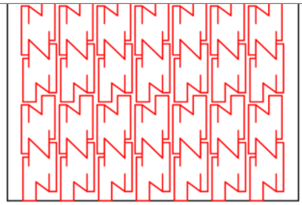
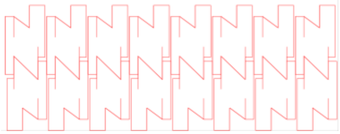
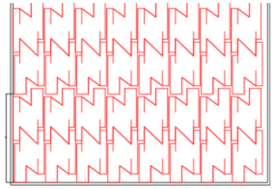
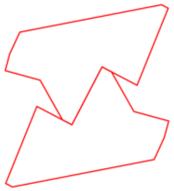
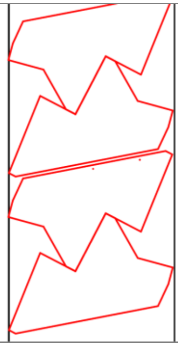
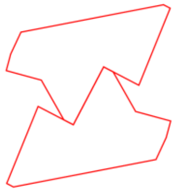
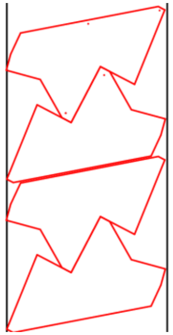
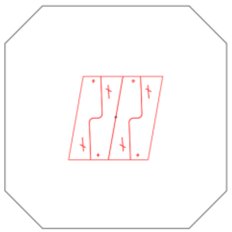
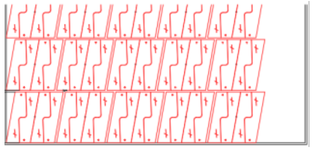
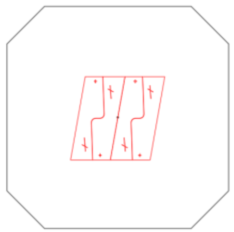
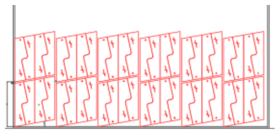
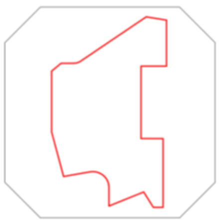
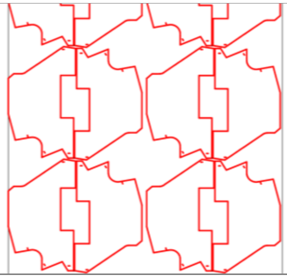
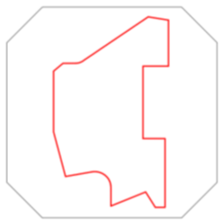
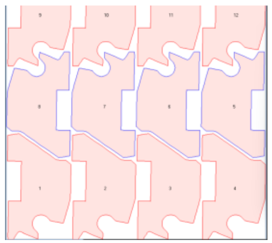
The results were an average of 216 s, considering that 380 observations were made, resulting in an associated error of 3.93 s and a standard deviation of 75.15 s.

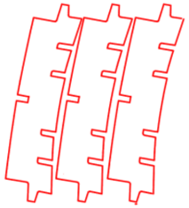
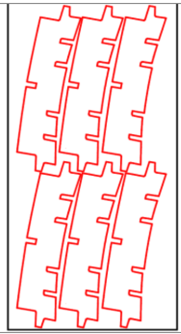
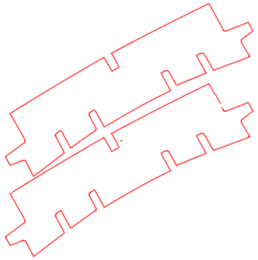
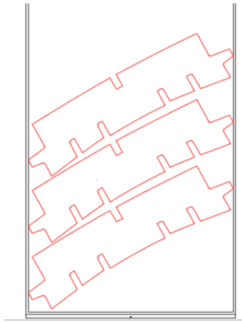
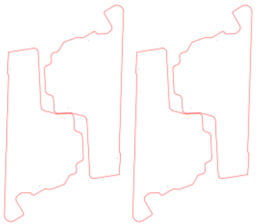
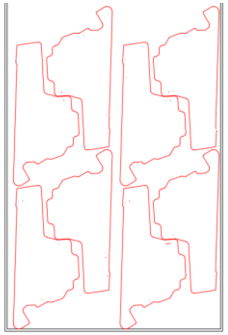
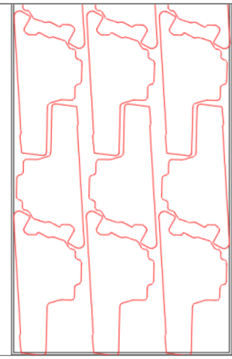
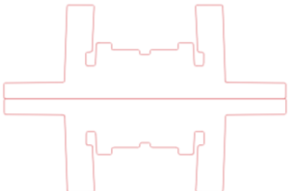
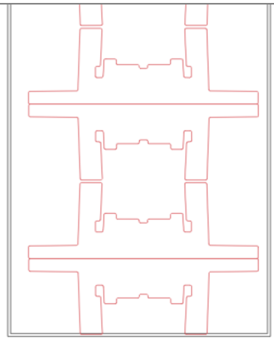
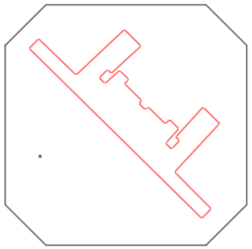
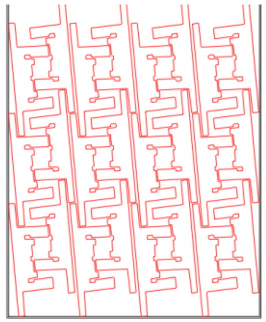
Appendix II - The initial and suggested tool's and yield's for each reference

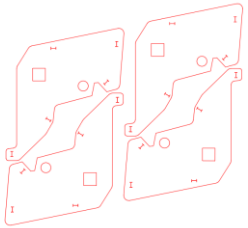
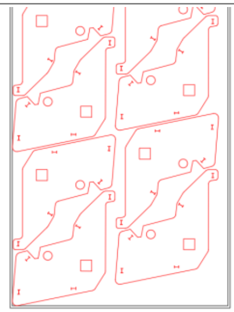
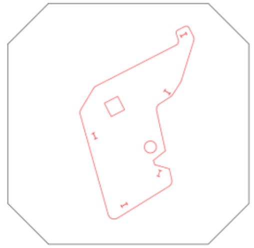
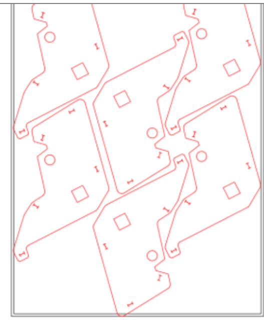
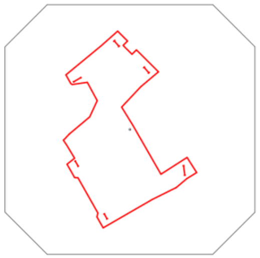
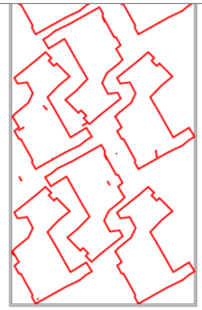
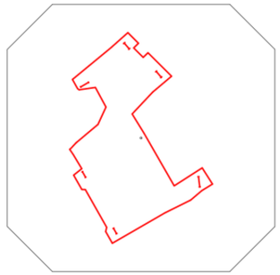
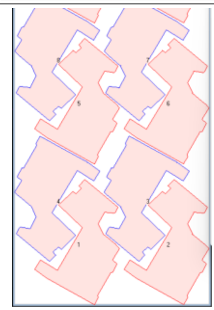
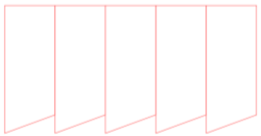
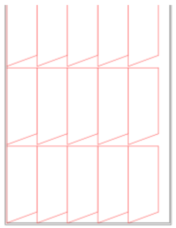
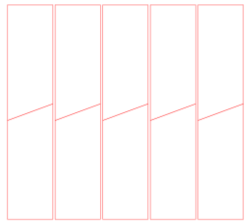
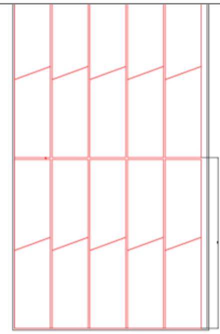
On the Table 16 is presented the suggestions made in order to improve the yield of the products in study.

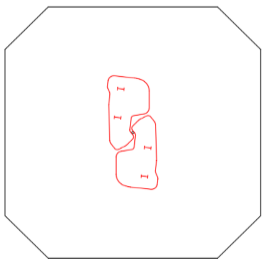
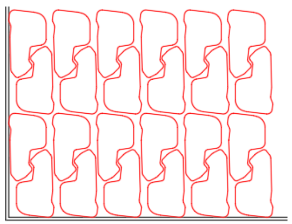
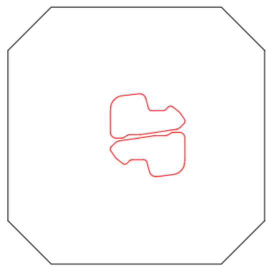
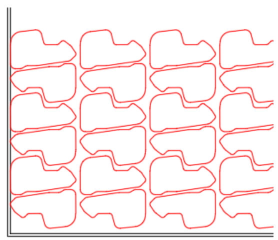
Table 16 - The initial and suggested tool's and yield's for each reference

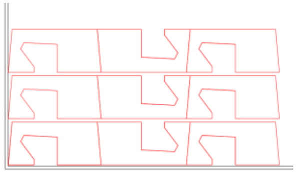
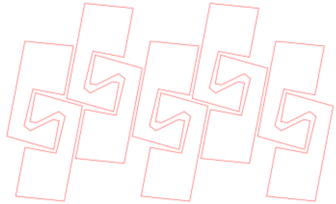
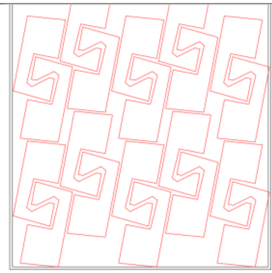
Reference	Initial				Suggestion			
	Tool	Distribution on the material	Yield (pc/m²)	Equipment	Tool	Distribution on the material	Yield (pc/m²)	Equipment
A_01			16.04	4 or 5			19.09	4 or 5
A_02			8.99	1, 2 or 3			10.44	4 or 5
A_03			8.99	1, 2 or 3			10.44	4 or 5

Reference	Initial				Suggestion			
	Tool	Distribution on the material	Yield (pc/m²)	Equipment	Tool	Distribution on the material	Yield (pc/m²)	Equipment
A_04			41.14	1, 2 or 3			47.06	1, 2 or 3
A_05			2.66	1, 2 or 3			2.69	1, 2 or 3
A_06			35.84	4 or 5			42.34	4 or 5
A_07			3.04	4 or 5			3.81	4 or 5

Reference	Initial				Suggestion			
	Tool	Distribution on the material	Yield (pc/m²)	Equipment	Tool	Distribution on the material	Yield (pc/m²)	Equipment
A_08			3.41	1, 2 or 3			3.89	1, 2 or 3
A_09			6.07	4 or 5			6.61	4 or 5
A_10			4.10	1, 2 or 3			6.92	1, 2 or 3

Reference	Initial				Suggestion			
	Tool	Distribution on the material	Yield (pc/m²)	Equipment	Tool	Distribution on the material	Yield (pc/m²)	Equipment
A_11			5.70	1, 2 or 3			6.19	4 or 5
A_12			4.14	4 or 5			5.71	4 or 5
A_13			8.45	1, 2 or 3			9.20	1, 2 or 3
A_14	Strips (0.014 x 1.35 x 0.015)	33 figures in width	46.20	6	Strips (0.0124 x 1.35 x 0.015)	40 figures in width	56.00	6
A_15	Strips (0.015 x 1.816 x 0.015)	33 figures in width	33.00	6	Strips (0.0145 x 1.816 x 0.015)	34 figures in width	34.00	6
A_16	Strips (0.015 x 1.36 x 0.015)	33 figures in width	46.20	6	Strips (0.0145 x 1.36 x 0.015)	34 figures in width	47.60	6
A_17	Strips (0.015 x 1.388 x 0.015)	33 figures in width	46.20	6	Strips (0.0145 x 1.388 x 0.015)	34 figures in width	47.60	6

Reference	Initial				Suggestion			
	Tool	Distribution on the material	Yield (pc/m²)	Equipment	Tool	Distribution on the material	Yield (pc/m²)	Equipment
A_18	Strips (0.015 x 1.345 x 0.015)	33 figures in width	46.20	6	Strips (0.0145 x 1.345 x 0.015)	34 figures in width	47.60	6
A_19	Strips (0.015 x 1.325 x 0.015)	33 figures in width	46.20	6	Strips (0.0145 x 1.325 x 0.015)	34 figures in width	47.60	6
A_20	Strips (0.010 x 0.64 x 0,.015)	48 figures in width	147.20	6	Strips (0.097 x 0.64 x 0.015)	51 figures in width	156.40	6
A_21	Strips (0.018 x 1.35 x 0.015)	27 figures in width	37.8	6	Strips (0.0177 x 1.35 x 0.015)	28 figures in width	39.20	6
A_22	Strips (0.015 x 1.37 x 0.015)	33 figures in width	46.20	6	Strips (0.0145 x 1.37 x 0.015)	34 figures in width	47.60	6
A_23	Strips (0.015 x 1.60 x 0.015)	33 figures in width	39.60	6	Strips (0.0145 x 1.60 x 0.015)	34 figures in width	40.80	6
A_24	Strips (0.015 x 1.325 x 0.015)	33 figures in width	46.20	6	Strips (0.0145 x 1.325 x 0.015)	34 figures in width	47.60	6
A_25	Strips (0.015 x 1.535 x 0.015)	33 figures in width	39.60	6	Strips (0.0145 x 1.535 x 0.015)	34 figures in width	40.80	6
A_26	Strips (0.015 x 1.343 x 0.015)	33 figures in width	48.40	6	Strips (0.0145 x 1.343 x 0.015)	34 figures in width	49.87	6
A_27	Strips (0.015 x 0.75 x 0.015)	33 figures in width	88.00	6	Strips (0.0145 x 0.75 x 0.015)	34 figures in width	90.67	6
A_28	Strips (0.010 x 0.426 x 0.015)	48 figures in width	220.80	6	Strips (0.0097 x 0.426 x 0.015)	51 figures in width	234.60	6
A_29	Strips (0.010 x 1.08 x 0.015)	48 figures in width	86.40	6	Strips (0.0097 x 1.08 x 0.015)	51 figures in width	91.80	6
A_30	Strips (0.015 x 1.36 x 0.015)	33 figures in width	46.20	6	Strips (0.0145 x 1.36 x 0.015)	34 figures in width	97.60	6
A_31	Strips (0.015 x 1.363 x 0.015)	33 figures in width	48.40	6	Strips (0.0145 x 1.363 x 0.015)	34 figures in width	49.87	6
A_32	Strips (0.015 x 1.36 x 0.015)	33 figures in width	48.40	6	Strips (0.0145 x 1.36 x 0.015)	34 figures in width	49.87	6
A_33	Strips (0.006 x 1.12 x 0.015)	41 figures in width	72.43	6	Strips (0.0058 x 1.12 x 0.015)	42 figures in width	74.20	6
A_34	Strips (0.015 x 1.325 x 0.015)	33 figures in width	49.5	6	Strips (0.0145 x 1.325 x 0.015)	34 figures in width	51.00	6
A_35	Strips (0.015 x 1.325 x 0.015)	33 figures in width	49.50	6	Strips (0.0145 x 1.325 x 0.015)	34 figures in width	51.00	6
A_36	Strips (0.010 x 0.635 x 0.015)	48 figures in width	150.40	6	Strips (0.0097 x 0.635 x 0.015)	51 figures in width	159.80	6
A_37	Strips (0.012 x 0.3 x 0.015)	40 figures in width	266.66	6	Strips (0.011 x 0.3 x 0.015)	45 figures in width	159.80	6
A_38	Strips (0.012 x 0.276 x 0.015)	40 figures in width	289.33	6	Strips (0.011 x 0.276 x 0.015)	45 figures in width	300.00	6
A_39	Strips (0.010 x 0.405 x 0.015)	48 figures in width	236.80	6	Strips (0.0097 x 0.405 x 0.015)	51 figures in width	251.60	6
A_40	Strips (0.006 x 1.58 x 0.015)	41 figures in width	101.13	6	Strips (0.0058 x 1.58 x 0.015)	42 figures in width	103.60	6
A_41			33.39	4 or 5			35.56	4 or 5

Reference	Initial				Suggestion			
	Tool	Distribution on the material	Yield (pc/m²)	Equipment	Tool	Distribution on the material	Yield (pc/m²)	Equipment
A_42			19.48	1, 2 or 3			20.92	1, 2 or 3

Appendix III – Equations to calculate the savings

In this appendix, it is presented the equations that were used to analyse the potential savings resulting from the suggestions provided to improve product productivity.

Saving material for the rest of the project

Equation 4 - Area of material saved

$$Area\ saved\ (m^2) = Area\ needed\ with\ initial\ Y - Area\ needed\ with\ suggested\ Y$$

Equation 5 - Number of rolls saved

$$Number\ of\ rolls\ saved\ (un) = Round\ Down\left(\frac{Area\ of\ material\ saved}{Area\ of\ the\ roll}\right)$$

Equation 6 - Percentage of material saved

$$Percentage\ o\ material\ saved\ (\%) = \frac{Area\ with\ Y\ initial - Area\ with\ Y\ suggested}{Area\ with\ Y\ initial} * 100$$

Equation 7 - Mass of material saved

$$Weight\ of\ material\ saved = Area\ saved \times Density\ of\ the\ material$$

Equation 8 - Monetary material saving

$$Material\ saving = Area\ saved \times Price\ of\ raw\ material$$

Saving containers for the rest of the project

Equation 9 - Number of containers saved

$$Number\ of\ containers\ saved\ =\ \frac{Area\ saved\ \times\ Thickness}{Volume\ of\ the\ container}$$

Equation 10 - Monetary saving of containers

$$Container\ saving\ (€) =\ \ Weight\ of\ the\ saved\ material \times Carrier\ price\ per + Nº\ of\ containers\ saved \times carrier\ price/transport$$

Saving equipment and labour for the rest of the project

Equation 11 - Monetary saving of equipment and labour

$$Equipment\ and\ labour\ saving\ (€)$$
$$= Time\ to\ change\ a\ roll \times Nº\ of\ rolls\ saved \times (Cost\ of\ equipment\ per\ hour + Cost\ of\ worker \times Nº\ of\ workers)$$

Total monetary savings for the rest of the project

Equation 12 - Total monetary saving

$$Total\ monetary\ saving\ (€) = Material\ saving\ +\ Container\ saving +\ Material\ and\ labour\ saving$$

CFP saving refers to the material saved

Equation 13 – Carbon Footprint saving referred to the material saved

$$CFP\ saving\ (kg\ \mathrm{CO_2}\ eq) = \frac{Weight\ of\ the\ material\ saved \times GHG\ Conversion\ Factor\ 2022}{1000}$$

Appendix IV – Savings of each reference for the remaining period of the project and per year

Table 17 represents the savings in material, containers, equipment, labour, total monetary savings, and associated carbon footprint (CFP) savings for each reference during the remaining period of the project. Table 18 shows the savings for the same parameters for each reference until the end of 2023, while Tables 19 to 29 represent the savings for subsequent years, up to 2035, with each table corresponding to a specific year.

Table 17 - Savings of material, containers, equipment, labour and total monetary saving and also of carbon footprint savings associated with material saved for each reference for the remaining period of the project

Ref.	Y Initial	Y suggested	SOP	EOP	Pieces per Year	Saving material					Saving containers		Saving in labour and equipment (€)	Total monetary saving (€)	CFP saving (kg CO_2 eq)
						Rolls (un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_01	16.04	19.09	2022	2028	92500	17	16	4 680.21	702.03	5 644.34	0.71	168.66	48.96	**5 861.96**	2 187.73
A_02	8.99	10.44	2023	2030	30000	25	14	3 401.96	510.29	8 056.53	0.52	122.60	120.00	**8 299.13**	1 590.23
A_03	8.99	10.44	2019	2030	140000	113	14	15 330.63	2 299.59	36 306.00	2.32	552.48	542.40	**37 400.89**	7 166.20
A_04	41.14	47.06	2013	2028	700000	53	13	10 706.22	5 299.58	43 560.38	4.87	1 212.89	248.04	**45 021.31**	16 515.02
A_05	2.66	2.69	2021	2029	277382	54	1	7 372.86	1 105.93	8 921.16	1.12	265.70	149.04	**9 335.91**	3 446.40
A_06	35.84	42.34	2021	2028	200000	24	15	4 358.57	871.71	6 937.53	1.06	231.27	69.12	**7 237.92**	2 716.51
A_07	3.04	3.81	2022	2028	92500	115	20	31 286.21	4 692.93	37 856.31	4.74	1 127.49	331.20	**39 315.00**	14 624.53
A_08	3.41	3.89	2022	2028	92500	126	12	17 029.35	2 554.40	20 605.51	2.58	613.70	347.76	**21 566.97**	7 960.26
A_09	6.07	6.61	2022	2028	99215	111	8	6 457.03	6 457.03	6 384.71	2.94	1 106.50	306.36	**7 797.57**	20 121.98
A_10	4.10	6.92	2022	2028	93195	349	41	47 146.91	7 073.07	57 056.06	7.14	1 699.32	963.24	**59 718.63**	22 041.72
A_11	5.70	6.19	2021	2028	106927	143	8	8 309.84	8 309.84	8 216.77	3.78	1 424.00	411.84	**10 052.62**	25 895.88
A_12	4.14	5.71	2021	2028	23911	139	27	8 079.55	8 079.55	7 572.97	2.45	1 232.74	667.20	**9 472.91**	25 178.23
A_13	8.42	9.20	2018	2025	103520	33	8	1 910.52	1 910.52	1 889.12	0.87	327.39	95.04	**2 311.56**	5 953.74
A_14	46.20	56.00	2016	2024	43048	35	18	176.91	344.97	5 596.71	0.08	49.64	71.40	**5 717.76**	1 075.04
A_15	33.00	34.00	2016	2030	140471	183	3	918.91	1 791.88	29 070.68	0.42	257.86	373.32	**29 701.86**	5 584.01
A_16	46.20	47.60	2018	2034	341062	492	3	2 462.75	4 802.36	77 911.49	1.12	691.08	1 003.68	**79 606.25**	14 965.54
A_17	46.20	47.60	2016	2030	140471	131	3	656.37	935.32	17 735.71	0.30	144.56	267.24	**18 147.51**	2 914.73
A_18	46.20	47.60	2017	2026	15329	5	3	27.65	53.91	874.59	0.01	7.76	10.20	**892.54**	167.99
A_19	46.20	47.60	2019	2030	179312	167	3	837.85	1 193.94	22 639.73	0.38	184.53	340.68	**23 164.94**	3 720.67
A_20	147.2	156.40	2020	2030	98088	39	6	297.47	5 577.60	7 024.98	0.14	658.19	79.56	**7 762.73**	17 381.42

A_21	37.80	39.20	2020	2029	58817	73	4	366.16	714.02	11 583.95	0.17	102.75	148.92	**11 835.62**	2 225.09
A_22	46.20	47.60	2019	2035	114665	172	3	864.17	1 231.45	23 350.94	0.39	190.32	350.88	**23 892.15**	3 837.55
A_23	39.60	40.80	2014	2029	75292	65	3	326.33	465.03	8 817.89	0.15	71.87	132.60	**9 022.36**	1 449.15
A_24	46.20	47.60	2019	2030	179312	167	3	837.85	1 193.94	22 639.73	0.38	184.53	340.68	**23 164.94**	3 720.67
A_25	39.60	40.80	2021	2031	138211	176	3	881.68	1 719.28	27 892.97	0.40	247.41	359.04	**28 499.42**	5 357.79
A_26	48.40	49.87	2016	2024	108419	1	3	49.64	25.32	499.13	0.02	5.71	2.04	**506.88**	78.89
A_27	88.00	90.67	2013	2029	800000	52	3	1 560.33	702.15	4 948.42	0.71	168.69	106.08	**5 223.19**	2 188.09
A_28	220.8	234.60	2022	2030	88088	34	6	172.25	335.88	5 449.17	0.08	48.33	69.36	**5 566.86**	1 046.70
A_29	86.40	91.80	2018	2027	18196	11	6	56.82	110.79	1 797.45	0.03	15.94	22.44	**1 835.84**	345.26
A_30	46.20	47.60	2021	2028	23911	15	3	77.45	151.02	2 450.06	0.04	21.73	30.60	**2 502.40**	470.62
A_31	48.40	49.87	2018	2034	341062	78	3	2 350.80	1 198.91	27 192.93	1.07	270.37	159.12	**27 622.43**	3 736.15
A_32	48.40	49.87	2018	2034	341062	78	3	2 350.80	1 198.91	27 192.93	1.07	270.37	159.12	**27 622.43**	3 736.15
A_33	72.43	74.20	2020	2030	98088	8	2	244.69	102.77	994.05	0.11	25.61	16.32	**1 035.98**	320.26
A_34	49.50	51.00	2019	2030	179312	26	3	782.00	398,82	9 045.75	0.36	89.94	53.04	**9 188.73**	1 242.83
A_35	49.50	51.00	2019	2030	179312	15	3	78.20	152.49	2 473.93	0.04	21.94	30.60	**2 526.47**	475.20
A_36	150.4	159.80	2020	2034	72835	10	6	323.11	135.71	1 267.37	0.15	33.82	20.40	**1 321.59**	422.90
A_37	266.7	300.00	2016	2024	44784	0	11	29.60	12.43	75.34	0.01	3.10	-	**78.43**	38.74
A_38	289.3	325.50	2016	2024	44784	0	11	27.28	11.46	69.43	0.01	2.86	-	**72.29**	35.71
A_39	236.8	251.60	2020	2034	72835	6	6	205.22	86.19	804.95	0.09	21.48	12.24	**838.67**	268.60
A_40	101.1	103.60	2017	2029	104137	5	2	155.43	151.54	424.62	0.07	26.19	10.20	**461.00**	472.25
A_41	33.38	35.56	2021	2028	189720	33	6	1 936.03	1 936.03	1 914.34	0.88	33176	95.04	**2 341.15**	6 033.22
A_42	19.48	20.92	2018	2025	51750	4	7	335.16	335.16	684.40	0.15	57.43	11.52	**753.36**	1 044.46
TOTAL	-	-	-	-	-	**3 383**		**185 465.64**	**76 935.76**	**591 431.06**	**40.12**	**14 290.56**	**8 576.52**	**614 298.14**	**239 754.14**

Table 18 - Savings of material, containers, equipment, labour and the monetary saving and also of carbon footprint saving associated with material saved for each reference until the end of 2023

Ref	Y initial	Y suggested	Missing pieces to 2023	Rolls (un)	Percentage (%)	Saving material Area (m^2)	Mass (kg)	Monetary (€)	Saving Containers Units	Monetary (€)	Saving in labour and equipment (€)	Saving total (€)	Saving CFP (kg CO_2 eq)
A_01	16.04	19.09	61582	2	16	612.43	91.87	738.60	0.09	22.07	5.76	766.43	286.3
A_02	8.99	10.44	19973	2	14	308.58	46.29	734.41	0.05	11.12	9.6	755.13	144.2
A_03	8.99	10.44	93205	10	14	1440.02	216.00	3427.26	0.22	51.90	48.00	3527.15	673.1
A_04	41.14	47.06	466027	7	13	1424.76	705.26	5813.02	0.65	161.41	32.76	6007.19	2 197.8
A_05	2.66	2.69	184668	5	1	774.25	116.14	936.84	0.12	27.90	13.8	978.54	361.9
A_06	35.84	42.34	133151	3	15	570.35	114.07	907.82	0.14	30.26	8.64	946.72	355.5
A_07	3.04	3.81	61582	15	20	4093.99	614.10	4953.73	0.62	147.54	43.2	5144.47	1 913.7
A_08	3.41	3.89	61582	16	12	2228.40	334.26	2696.36	0.34	80.31	44.16	2820.83	1 041.6
A_09	6.07	6.61	66053	15	8	888.98	888.98	897.87	0.40	152.34	41.4	1091.61	2 770.3
A_10	4.10	6.92	62045	22	41	6170.36	925.55	7466.14	0.93	222.37	63.36	7751.87	2 884.3
A_11	5.70	6.19	71187	17	8	989.85	989.85	999.75	0.45	169.62	48.96	1218.33	3 084.7
A_12	4.14	5.71	15919	18	27	1057.26	1057.26	990.97	0.32	161.31	86.4	1238.68	3 294.7
A_13	8.42	9.20	68919	12	8	693.96	693.96	700.90	0.32	118.92	34.56	854.38	2 162.6
A_14	46.20	56.00	28659	21	18	108.56	211.69	3434.35	0.05	30.46	42.84	3507.65	659.7
A_15	33.00	34.00	93519	16	3	83.35	162.53	2636.87	0.04	23.39	32.64	2692.90	506.5
A_16	46.20	47.60	227063	28	3	144.55	281.88	457307	0.07	40.56	57.12	4670.75	878.4
A_17	46.20	47.60	93519	11	3	59.54	84.84	1608.73	0.03	13.11	22.44	1644.28	264.4
A_18	46.20	47.60	10205	1	3	6.50	12.67	205.54	0.00	1.82	2.04	209.40	39.5
A_19	46.20	47.60	119378	15	3	76.00	108.30	2053.55	0.03	16.74	30.6	2100.89	337.5
A_20	147.2	156.40	65302	3	6	26.10	489.30	616.27	0.01	57.74	6.12	680.13	1 524.8
A_21	37.80	39.20	39158	7	4	37.00	72.14	1170.44	0.02	10.38	14.28	1195.10	224.8
A_22	46.20	47.60	76339	9	3	48.60	69.25	1313.19	0.02	10.70	18.36	1342.25	215.8
A_23	39.60	40.80	50126	7	3	37.23	53.05	1005.98	0.02	8.20	14.28	1028.46	165.3
A_24	46.20	47.60	119378	15	3	76.00	108.30	2053.55	0.03	16.74	30.6	2100.89	337.5
A_25	39.60	40.80	92014	13	3	68.34	133.27	2162.04	0.03	19.18	26.52	2207.74	415.3
A_26	48.40	49.87	72180	1	3	43.86	22.37	441.05	0.02	5.04	2.04	448.14	69.7
A_27	88.00	90.67	532603	5	3	178.01	80.10	564.54	0.08	19.25	10.2	593.98	249.6
A_28	220.8	234.60	58645	3	6	15.62	30.47	494.27	0.01	4.38	6.12	504.77	94.9
A_29	86.40	91.80	12114	1	6	8.25	16.08	260.92	0.00	2.31	2.04	265.27	50.1
A_30	46.20	47.60	15919	2	3	10.13	19.76	320.61	0.00	2.84	4.08	327.53	61.6
A_31	48.40	49.87	227063	4	3	137.98	70.37	1596.11	0.06	15.87	8.16	1620.14	219.3
A_32	48.40	49.87	227063	4	3	137.98	70.37	1596.11	0.06	15.87	8.16	1620.14	219.3

Ref	Y initial	Y suggested	Missing pieces to 2023	Rolls (un)	Percentage (%)	Saving material Area (m²)	Mass (kg)	Monetary (€)	Saving Containers Units	Monetary (€)	Saving in labour and equipment (€)	Saving total (€)	Saving CFP (kg CO_2 eq)
A_33	72.43	74.20	65302	0	2	21.47	9.02	87.20	0.01	2.25	0	89.45	28.1
A_34	49.50	51.00	119378	2	3	70.93	36.18	820.50	0.03	8.16	4.08	832.74	112.7
A_35	49.50	51.00	119378	1	3	7.09	13.83	224.40	0,00	1.99	2.04	228.43	43.1
A_36	150.4	159.80	48490	0	6	18.97	7.97	74.39	0.01	1.98	0	76.37	24.8
A_37	266.7	300.00	29815	0	11	12.42	5.22	31.62	0.01	1.30	0	32.92	16.3
A_38	289.3	325.50	29815	0	11	11.45	4.81	29.14	0.01	1.20	0	30.34	15.0
A_39	236.8	251.60	48490	0	6	12.05	5.06	47.25	0.01	1.26	0	48.51	15.8
A_40	101.1	103.60	69330	0	2	16.32	15.91	44.59	0.01	2.75	0	47.34	49.6
A_41	33.38	35.56	126307	3	6	230.62	230.62	228.03	0.10	39.52	6.12	273.67	718.7
A_42	19.48	20.92	34453	1	7	121.74	121.74	248.59	0.06	20.86	2.04	271.50	379.4
Total				316		23 079.84	9 340.66	61 206.53	5.48	1 752.94	833.52	63 792.99	29 108.2

Table 19 - Savings of material, containers, equipment, labour and total monetary saving and also of carbon footprint savings associated with material saved for each reference except to 2024

Ref	Y initial	Y suggested	Production to 2024	Rolls (un)	Percentage (%)	Saving material			Saving containers		Saving in labour and equipment (€)	Total Saving (€)	Saving CFP (kg CO_2 eq)
						Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_01	16.04	19.09	92500	3	16	919.91	137.99	1109.41	0.14	33.15	8.64	1151.21	430.01
A_02	8.99	10.44	30000	3	14	463.50	69.52	1103.13	0.07	16.70	14.40	1134.23	216.66
A_03	8.99	10.44	140000	16	14	2 163.00	324.45	5147.94	0.33	77.95	76.80	5302.69	1011.08
A_04	41.14	47.06	700000	10	13	2 140.07	1 059.33	8731.49	0.97	242.45	46.80	9020.73	3301.19
A_05	2.66	2.69	277382	8	1	1 162.96	174.44	1407.18	0.18	41.91	22.08	1471.18	543.62
A_06	35.84	42.34	200000	4	15	856.69	171.34	1363.60	0.21	45.46	11.52	1420.57	533.94
A_07	3.04	3.81	92500	22	20	6 149.42	922.41	7440.79	0.93	221.61	63.36	7725.77	2874.50
A_08	3.41	3.89	92500	24	12	3 347.18	502.08	4050.09	0.51	120.63	66.24	4236.95	1564.62
A_09	6.07	6.61	99215	23	8	1 335.31	1 335.31	1348.66	0.61	228.82	63.48	1640.96	4161.20
A_10	4.10	6.92	93195	34	41	9 268.24	1 390.24	11214.57	1.40	334.01	97.92	11646.50	4332.38
A_11	5.70	6.19	106927	25	8	1 486.81	1 486.81	1501.68	0.68	254.79	72.00	1828.46	4633.33
A_12	4.14	5.71	23911	27	27	1 588.07	1 588.07	1488.49	0.48	242.30	129.60	1860.39	4948.87
A_13	8.42	9.20	103520	18	8	1 042.36	1 042.36	1052.79	0.47	178.62	51.84	1283.25	3248.31
A_14	46.20	56.00	17927	13	18	67.90	132.41	2148.23	0.03	19.05	26.52	2193.81	412.64
A_15	33.00	34.00	140471	25	3	125.20	244.13	3960.73	0.06	35.13	51.00	4046.86	760.79
A_16	46.20	47.60	341062	43	3	217.13	423.40	6869.01	0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	140471	17	3	89.43	127.43	2416.40	0.04	19.70	34.68	2470.78	397.12
A_18	46.20	47.60	15329	1	3	9.76	19.03	308.73	0.00	2.74	2.04	313.51	59.30
A_19	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_20	147.2	156.40	98088	5	6	39.20	734.95	925.67	0.02	86.73	10.20	1022.60	2290.33
A_21	37.80	39.20	58817	11	4	55.57	108.36	1758.06	0.03	15.59	22.44	1796.10	337.70
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	75292	11	3	55.92	79.69	1511.05	0.03	12.32	22.44	1545.80	248.33
A_24	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_25	39.60	40.80	138211	20	3	102.65	200.17	3247.51	0.05	28.81	40.80	3317.11	623.79
A_26	48.40	49.87	9208	0	3	5.60	2.85	56.27	0.00	0.64	0.00	56.91	8.89
A_27	88.00	90.67	800000	8	3	267.38	120.32	847.97	0.12	28.91	16.32	893.20	374.95
A_28	220.8	234.60	88088	4	6	23.47	45.76	742.42	0.01	6.59	8.16	757.17	142.61
A_29	86.40	91.80	18196	2	6	12.39	24.16	391.92	0.01	3.48	4.08	399.47	75.28
A_30	46.20	47.60	23911	3	3	15.22	29.68	481.57	0.01	4.27	6.12	491.96	92.50
A_31	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40
A_32	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40

Ref	Y initial	Y suggested	Production to 2024	Rolls (un)	Percentage (%)	Saving material Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving in labour and equipment (€)	Total Saving (€)	Saving CFP (kg CO_2 eq)
A_33	72.43	74.20	98088	1	2	32.24	13.54	130.98	0.01	3.37	2.04	136.40	42.20
A_34	49.50	51.00	179312	3	3	106.54	54.34	1232.44	0.05	12.25	6.12	1250.81	169.33
A_35	49.50	51.00	179312	2	3	10.65	20.78	337.06	0.00	2.99	4.08	344.13	64.74
A_36	150.4	159.80	72835	0	6	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	41103	0	11	17.13	7.19	43.59	0.01	1.79	0.00	45.38	22.42
A_38	289.3	325.50	41103	0	11	15.78	6.63	40.17	0.01	1.65	0.00	41.83	20.66
A_39	236.8	251.60	72835	0	6	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60	104137	0	2	24.52	23.90	66.98	0.01	4.13	0.00	71.11	74.49
A_41	33.38	35.56	189720	5	6	346.40	346.40	342.52	0.16	59.36	10.20	412.08	1079.47
A_42	19.48	20.92	51750	2	7	182.86	182.86	373.40	0.08	31.34	4.08	408.82	569.85
Total				461		34 508.85	13 812.68	88 311.67	8.14	2 599.07	1 226.52	92 137.26	43 044.30

Table 20 - Savings of material, containers, equipment, labour and total monetary saving and also of carbon footprint savings associated with material saved for each reference except to 2025

Ref	Y initial	Y suggested	Pieces to 2025	Rolls	Saving material				Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
				(un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_01	16.04	19.09	92500	3	16	919.91	137.99	1109.41	0.14	33.15	8.64	1151.21	430.01
A_02	8.99	10.44	30000	3	14	463.50	69.52	1103.13	0.07	16.70	14.40	1134.23	216.66
A_03	8.99	10.44	140000	16	14	2163.00	324.45	5147.94	0.33	77.95	76.80	5302.69	1011.08
A_04	41.14	47.06	700000	10	13	2140.07	1059.33	8731.49	0.97	242.45	46.80	9020.73	3301.19
A_05	2.66	2.69	277382	8	1	1162.96	174.44	1407.18	0.18	41.91	22.08	1471.18	543.62
A_06	35.84	42.34	200000	4	15	856.69	171.34	1363.60	0.21	45.46	11.52	1420.57	533.94
A_07	3.04	3.81	92500	22	20	6149.42	922.41	7440.79	0.93	221.61	63.36	7725.77	2874.50
A_08	3.41	3.89	92500	24	12	3347.18	502.08	4050.09	0.51	120.63	66.24	4236.95	1564.62
A_09	6.07	6.61	99215	23	8	1335.31	1335.31	1348.66	0.61	228.82	63.48	1640.96	4161.20
A_10	4.10	6.92	93195	34	41	9268.24	1390.24	11214.57	1.40	334.01	97.92	11646.50	4332.38
A_11	5.70	6.19	106927	25	8	1486.81	1486.81	1501.68	0.68	254.79	72.00	1828.46	4633.33
A_12	4.14	5.71	23911	27	27	1588.07	1588.07	1488.49	0.48	242.30	129.60	1860.39	4948.87
A_13	8.42	9.20	103520	18	8	1042.36	1042.36	1052.79	0.47	178.62	66.96	1298.37	3248.31
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	140471	25	3	125.20	244.13	3960.73	0.06	35.13	51.00	4046.86	760.79
A_16	46.20	47.60	341062	43	3	217.13	423.40	6869.01	0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	140471	17	3	89.43	127.43	2416.40	0.04	19.70	34.68	2470.78	397.12
A_18	46.20	47.60	15329	1	3	9.76	19.03	308.73	0.00	2.74	2.04	313.51	59.30
A_19	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_20	147.2	156.40	98088	5	6	39.20	734.95	925.67	0.02	86.73	10.20	1022.60	2290.33
A_21	37.80	39.20	58817	11	4	55.57	108.36	1758.06	0.03	15.59	22.44	1796.10	337.70
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	75292	11	3	55.92	79.69	1511.05	0.03	12.32	22.44	1545.80	248.33
A_24	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_25	39.60	40.80	138211	20	3	102.65	200.17	3247.51	0.05	28.81	40.80	3317.11	623.79
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	800000	8	3	267.38	120.32	847.97	0.12	28.91	16.32	893.20	374.95
A_28	220.8	234.60	88088	4	6	23.47	45.76	742.42	0.01	6.59	8.16	757.17	142.61
A_29	86.40	91.80	18196	2	6	12.39	24.16	391.92	0.01	3.48	4.08	399.47	75.28
A_30	46.20	47.60	23911	3	3	15.22	29.68	481.57	0.01	4.27	6.12	491.96	92.50
A_31	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40

Ref	Y initial	Y suggested	Pieces to 2025	Rolls (un)	Saving material				Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
					Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_32	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40
A_33	72.43	74.20	98088	1	2	32.24	13.54	130.98	0.01	3.37	2.04	136.40	42.20
A_34	49.50	51.00	179312	3	3	106.54	54.34	1232.44	0.05	12.25	6.12	1250.81	169.33
A_35	49.50	51.00	179312	2	3	10.65	20.78	337.06	0.00	2.99	4.08	344.13	64.74
A_36	150.4	159.80	72835	0	6	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60	104137	0	2	24.52	23.90	66.98	0.01	4.13	0.00	71.11	74.49
A_41	33.38	35.56	189720	5	6	346.40	346.40	342.52	0.16	59.36	10.20	412.08	1079.47
A_42	19.48	20.92	8365	0	7	29.56	29.56	60.36	0.01	5.07	0.00	65.42	92.11
Total				**448.00**		**34 249.14**	**13 510.28**	**85 710.36**	**8.03**	**2 549.66**	**1 211.04**	**89 471.06**	**42 101.96**

Table 21 - Savings of material, containers, equipment, labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2026

Ref	Y initial	Y suggested	Pieces expected to 2026	Saving material					Saving containers		Saving in labour and equipment (€)	Total saving	Saving CFP (kg CO_2 eq)
				Rolls (un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_01	16.04	19.09	92500	3	16	919.91	137.99	1109.41	0.14	33.15	8.64	1151.21	430.01
A_02	8.99	10.44	30000	3	14	463.50	69.52	1103.13	0.07	16.70	14.40	1134.23	216.66
A_03	8.99	10.44	140000	16	14	2163.00	324.45	5147.94	0.33	77.95	76.80	5302.69	1011.08
A_04	41.14	47.06	700000	10	13	2140.07	1059.33	8731.49	0.97	242.45	46.80	9020.73	3301.19
A_05	2.66	2.69	277382	8	1	1162.96	174.44	1407.18	0.18	41.91	22.08	1471.18	543.62
A_06	35.84	42.34	200000	4	15	856.69	171.34	1363.60	0.21	45.46	11.52	1420.57	533.94
A_07	3.04	3.81	92500	22	20	6149.42	922.41	7440.79	0.93	221.61	63.36	7725.77	2874.50
A_08	3.41	3.89	92500	24	12	3347.18	502.08	4050.09	0.51	120.63	66.24	4236.95	1564.62
A_09	6.07	6.61	99215	23	8	1335.31	1335.31	1348.66	0.61	228.82	63.48	1640.96	4161.20
A_10	4.10	6.92	93195	34	41	9268.24	1390.24	11214.57	1.40	334.01	97.92	11646.50	4332.38
A_11	5.70	6.19	106927	25	8	1486.81	1486.81	1501.68	0.68	254.79	72.00	1828.46	4633.33
A_12	4.14	5.71	23911	27	27	1588.07	1588.07	1488.49	0.48	242.30	129.60	1860.39	4948.87
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	140471	25	3	125.20	244.13	3960.73	0.06	35.13	51.00	4046.86	760.79
A_16	46.20	47.60	341062	43	3	217.13	423.40	6869.01	0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	140471	17	3	89.43	127.43	2416.40	0.04	19.70	34.68	2470.78	397.12
A_18	46.20	47.60	2478	0	3	1.58	3.08	49.90	0.00	0.44	0.00	50.35	9.59
A_19	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_20	147.2	156.40	98088	5	6	39.20	734.95	925.67	0.02	86.73	10.20	1022.60	2290.33
A_21	37.80	39.20	58817	11	4	55.57	108.36	1758.06	0.03	15.59	22.44	1796.10	337.70
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	75292	11	3	55.92	79.69	1511.05	0.03	12.32	22.44	1545.80	248.33
A_24	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_25	39.60	40.80	138211	20	3	102.65	200.17	3247.51	0.05	28.81	40.80	3317.11	623.79
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	800000	8	3	267.38	120.32	847.97	0.12	28.91	16.32	893.20	374.95
A_28	220.8	234.60	88088	4	6	23.47	45.76	742.42	0.01	6.59	8.16	757.17	142.61
A_29	86.40	91.80	18196	2	6	12.39	24.16	391.92	0.01	3.48	4.08	399.47	75.28
A_30	46.20	47.60	23911	3	3	15.22	29.68	481.57	0.01	4.27	6.12	491.96	92.50
A_31	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40
A_32	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40

Ref	Y initial	Y suggested	Pieces expected to 2026	Rolls (un)	Saving material Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving in labour and equipment (€)	Total saving	Saving CFP (kg CO_2 eq)
A_33	72.43	74.20	98088	1	2	32.24	13.54	130.98	0.01	3.37	2.04	136.40	42.20
A_34	49.50	51.00	179312	3	3	106.54	54.34	1232.44	0.05	12.25	6.12	1250.81	169.33
A_35	49.50	51.00	179312	2	3	10.65	20.78	337.06	0.00	2.99	4.08	344.13	64.74
A_36	150.4	159.80	72835	0	6	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60	104137	0	2	24.52	23.90	66.98	0.01	4.13	0.00	71.11	74.49
A_41	33.38	35.56	189720	5	6	346.40	346.40	342.52	0.16	59.36	10.20	412.08	1079.47
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				429.00		33169.04	12422.41	84338.39	7.54	2363.67	1142.04	87844.11	38711.82

Table 22 - Savings of material, containers, equipment, labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2027

Ref	Y initial	Y suggested	Pieces excepted to 2027	Rolls (un)	Saving material				Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
					Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_01	16.04	19.09	92500	3	16	919.91	137.99	1109.41	0.14	33.15	8.64	1151.21	430.01
A_02	8.99	10.44	30000	3	14	463.50	69.52	1103.13	0.07	16.70	14.40	1134.23	216.66
A_03	8.99	10.44	140000	16	14	2163.00	324.45	5147.94	0.33	77.95	76.80	5302.69	1011.08
A_04	41.14	47.06	700000	10	13	2140.07	1059.33	8731.49	0.97	242.45	46.80	9020.73	3301.19
A_05	2.66	2.69	277382	8	1	1162.96	174.44	1407.18	0.18	41.91	22.08	1471.18	543.62
A_06	35.84	42.34	200000	4	15	856.69	171.34	1363.60	0.21	45.46	11.52	1420.57	533.94
A_07	3.04	3.81	92500	22	20	6149.42	922.41	7440.79	0.93	221.61	63.36	7725.77	2874.50
A_08	3.41	3.89	92500	24	12	3347.18	502.08	4050.09	0.51	120.63	66.24	4236.95	1564.62
A_09	6.07	6.61	99215	23	8	1335.31	1335.31	1348.66	0.61	228.82	63.48	1640.96	4161.20
A_10	4.10	6.92	93195	34	41	9268.24	1390.24	11214.57	1.40	334.01	97.92	11646.50	4332.38
A_11	5.70	6.19	106927	25	8	1486.81	1486.81	1501.68	0.68	254.79	72.00	1828.46	4633.33
A_12	4.14	5.71	23911	27	27	1588.07	1588.07	1488.49	0.48	242.30	129.60	1860.39	4948.87
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	140471	25	3	125.20	244.13	3960.73	0.06	35.13	51.00	4046.86	760.79
A_16	46.20	47.60	341062	43	3	217.13	423.40	6869.01	0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	140471	17	3	89.43	127.43	2416.40	0.04	19.70	34.68	2470.78	397.12
A_18	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_19	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_20	147.2	156.40	98088	5	6	39.20	734.95	925.67	0.02	86.73	10.20	1022.60	2290.33
A_21	37.80	39.20	58817	11	4	55.57	108.36	1758.06	0.03	15.59	22.44	1796.10	337.70
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	75292	11	3	55.92	79.69	1511.05	0.03	12.32	22.44	1545.80	248.33
A_24	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_25	39.60	40.80	138211	20	3	102.65	200.17	3247.51	0.05	28.81	40.80	3317.11	623.79
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	800000	8	3	267.38	120.32	847.97	0.12	28.91	16.32	893.20	374.95
A_28	220.8	234.60	88088	4	6	23.47	45.76	742.42	0.01	6.59	8.16	757.17	142.61
A_29	86.40	91.80	16651	2	6	11.34	22.11	358.63	0.01	3.18	4.08	365.89	68.89
A_30	46.20	47.60	23911	3	3	15.22	29.68	481.57	0.01	4.27	6.12	491.96	92.50
A_31	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40
A_32	48.40	49.87	312095	6	3	189.65	96.72	2193.83	0.09	21.81	12.24	2227.88	301.42

Ref	Y initial	Y suggested	Pieces excepted to 2027	Rolls (un)	Percentage (%)	Saving material			Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
						Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_33	72.43	74.20	98088	1	2	32.24	13.54	130.98	0.01	3.37	2.04	136.40	42.20
A_34	49.50	51.00	179312	3	3	106.54	54.34	1232.44	0.05	12.25	6.12	1250.81	169.33
A_35	49.50	51.00	164083	1	3	9.75	19.01	308.43	0.00	2.74	2.04	313.21	59.24
A_36	150.4	159.80	72835	0	6	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60	95292	0	2	22.43	21.87	61.29	0.01	3.78	0.00	65.07	68.16
A_41	33.38	35.56	189720	5	6	346.40	346.40	342.52	0.16	59.36	10.20	412.08	1079.47
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				428.00		33145.82	12404.51	84017.27	7.53	2360.31	1140.00	87517.58	38656.04

Table 23 - Savings of material, containers, equipment, labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2028

Ref	Y initial	Y suggested	Pieces excepted to 2028	Rolls (un)	Saving material				Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
					Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_01	16.04	19.09	38521	1	16	383.09	57.46	462.00	0.06	13.81	2.88	478.69	179.07
A_02	8.99	10.44	30000	3	14	463.50	69.52	1103.13	0.07	16.70	14.40	1134.23	216.66
A_03	8.99	10.44	140000	16	14	2163.00	324.45	5147.94	0.33	77.95	76.80	5302.69	1011.08
A_04	41.14	47.06	232055	3	13	709.45	351.18	2894.55	0.32	80.37	14.04	2988.96	1094.37
A_05	2.66	2.69	277382	8	1	1162.96	174.44	1407.18	0.18	41.91	22.08	1471.18	543.62
A_06	35.84	42.34	83288	1	15	356.76	71.35	567.85	0.09	18.93	2.88	589.66	222.35
A_07	3.04	3.81	38521	9	20	2560.85	384.13	3098.63	0.39	92.29	25.92	3216.84	1197.05
A_08	3.41	3.89	38521	10	12	1393.89	209.08	1686.61	0.21	50.23	27.60	1764.44	651.57
A_09	6.07	6.61	16309	3	8	219.50	219.50	221.70	0.10	37.61	8.28	267.59	684.03
A_10	4.10	6.92	38810	14	41	3859.65	578.95	4670.18	0.58	139.09	40.32	4849.59	1804.17
A_11	5.70	6.19	98138	23	8	1364.61	1364.61	1378.25	0.62	233.84	66.24	1678.34	4252.51
A_12	4.14	5.71	9957	11	27	661.33	661.33	619.87	0.20	100.90	52.80	773.57	2060.90
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	140471	25	3	125.20	244.13	3960.73	0.06	35.13	51.00	4046.86	760.79
A_16	46.20	47.60	341062	43	3	217.13	423.40	6869.01	0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	140471	17	3	89.43	127.43	2416.40	0.04	19.70	34.68	2470.78	397.12
A_18	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_19	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_20	147.2	156.40	98088	5	6	39.20	734.95	925.67	0.02	86.73	10.20	1022.60	2290.33
A_21	37.80	39.20	58817	11	4	55.57	108.36	1758.06	0.03	15.59	22.44	1796.10	337.70
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	75292	11	3	55.92	79.69	1511.05	0.03	12.32	22.44	1545.80	248.33
A_24	46.20	47.60	179312	22	3	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_25	39.60	40.80	138211	20	3	102.65	200.17	3247.51	0.05	28.81	40.80	3317.11	623.79
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	800000	8	3	267.38	120.32	847.97	0.12	28.91	16.32	893.20	374.95
A_28	220.8	234.60	88088	4	6	23.47	45.76	742.42	0.01	6.59	8.16	757.17	142.61
A_29	86.40	91.80	-	-	-	-	-	-	-	-	-	-	-
A_30	46.20	47.60	9957	1	3	6.34	12.36	200.54	0.00	1.78	2.04	204.36	38.52
A_31	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40
A_32	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40

Ref	Y initial	Y suggested	Pieces excepted to 2028	Rolls (un)	Percentage (%)	Saving material Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
A_33	72.43	74.20	98088	1	2	32.24	13.54	130.98	0.01	3.37	2.04	136.40	42.20
A_34	49.50	51.00	179312	3	3	106.54	54.34	1232.44	0.05	12.25	6.12	1250.81	169.33
A_35	49.50	51.00	179312	2	3	10.65	20.78	337.06	0.00	2.99	4.08	344.13	64.74
A_36	150.4	159.80	72835	0	6	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60	104137	0	2	24.52	23.90	66.98	0.01	4.13	0.00	71.11	74.49
A_41	33.38	35.56	174127	5	6	317.93	317.93	314.37	0.14	54.48	10.20	379.05	990.75
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				328.00		17535.15	7653.41	60938.25	4.16	1396.26	815.28	63149.79	23850.23

Table 24 - Savings of material, containers, equipment labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2029

Ref	Y initial	Y suggested	Pieces excepted to 2029	Rolls (un)	Saving material Percentage (%)	Saving material Area (m^2)	Saving material Mass (kg)	Saving material Monetary (€)	Saving containers Units	Saving containers Monetary (€)	Saving labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
A_01	16.04	19.09	-	-	-	-	-	-	-	-	-	-	-
A_02	8.99	10.44	30000	3	14%	463.50	69.52	1103.13	0.07	16.70	14.40	1134.23	216.66
A_03	8.99	10.44	140000	16	14%	2163.00	324.45	5147.94	0.33	77.95	76.80	5302.69	1011.08
A_04	41.14	47.06											0.00
A_05	2.66	2.69	184668	5	1%	774.25	116.14	936.84	0.12	27.90	13.80	978.54	361.92
A_06	35.84	42.34	-	-	-	-	-	-	-	-	-	-	-
A_07	3.04	3.81	-	-	-	-	-	-	-	-	-	-	-
A_08	3.41	3.89	-	-	-	-	-	-	-	-	-	-	-
A_09	6.07	6.61	-	-	-	-	-	-	-	-	-	-	-
A_10	4.10	6.92	-	-	-	-	-	-	-	-	-	-	-
A_11	5.70	6.19	-	-	-	-	-	-	-	-	-	-	-
A_12	4.14	5.71	-	-	-	-	-	-	-	-	-	-	-
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	140471	25	3%	125.20	244.13	3960.73	0.06	35.13	51.00	4046.86	760.79
A_16	46.20	47.60	341062	43	3%	217.13	423.40	6869.01	0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	140471	17	3%	89.43	127.43	2416.40	0.04	19.70	34.68	2470.78	397.12
A_18	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_19	46.20	47.60	179312	22	3%	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_20	147.2	156.40	98088	5	6%	39.20	734.95	925.67	0.02	86.73	10.20	1022.60	2290.33
A_21	37.80	39.20	53822	10	4%	50.85	99.16	1608.75	0.02	14.27	20.40	1643.42	309.01
A_22	46.20	47.60	114665	14	3%	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	12170	1	3%	9.04	12.88	244.25	0.00	1.99	2.04	248.28	40.14
A_24	46.20	47.60	179312	22	3%	114.15	162.67	3084.55	0.05	25.14	44.88	3154.57	506.92
A_25	39.60	40.80	138211	20	3%	102.65	200.17	3247.51	0.05	28.81	40.80	3317.11	623.79
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	129315	1	3%	43.22	19.45	137.07	0.02	4.67	2.04	143.78	60.61
A_28	220.8	234.60	88088	4	6%	23.47	45.76	742.42	0.01	6.59	8.16	757.17	142.61
A_29	86.40	91.80	-	-	-	-	-	-	-	-	-	-	-
A_30	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_31	48.40	49.87	341062	6	3%	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40
A_32	48.40	49.87	341062	6	3%	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40

Ref	Y initial	Y suggested	Pieces excepted to 2029	Rolls (un)	Saving material Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
A_33	72.43	74.20	98088	1	2%	32.24	13.54	130.98	0.01	3.37	2.04	136.40	42.20
A_34	49.50	51.00	179312	3	3%	106.54	54.34	1232.44	0.05	12.25	6.12	1250.81	169.33
A_35	49.50	51.00	179312	2	3%	10.65	20.78	337.06	0.00	2.99	4.08	344.13	64.74
A_36	150.4	159.80	72835	0	6%	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6%	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60	69330	0	2%	16.32	15.91	44.59	0.01	2.75	0.00	47.34	49.59
A_41	33.38	35.56	-	-	-	-	-	-	-	-	-	-	-
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				226.00		5029.08	3182.35	42203.96	1.26	521.64	517.08	43242.68	9917.12

Table 25 - Savings of material, containers, equipment, labour and total monetary saving and also of carbon footprint saving associated with material saved for each reference except to 2030

Ref	Y initial	Y suggested	Pieces excepted to 2030	Saving material					Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
				Rolls (un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_01	16.04	19.09	-	-	-	-	-	-	-	-	-	-	-
A_02	8.99	10.44	19973	2	14	308.58	46.29	734.41	0.05	11.12	9.60	755.13	144.24
A_03	8.99	10.44	57918	6	14	894.83	134.22	2129.70	0.14	32.25	28.80	2190.74	418.28
A_04	41.14	47.06	-	-	-	-	-	-	-	-	-	-	-
A_05	2.66	2.69	-	-	-	-	-	-	-	-	-	-	-
A_06	35.84	42.34	-	-	-	-	-	-	-	-	-	-	-
A_07	3.04	3.81	-	-	-	-	-	-	-	-	-	-	-
A_08	3.41	3.89	-	-	-	-	-	-	-	-	-	-	-
A_09	6.07	6.61	-	-	-	-	-	-	-	-	-	-	-
A_10	4.10	6.92	-	-	-	-	-	-	-	-	-	-	-
A_11	5.70	6.19	-	-	-	-	-	-	-	-	-	-	-
A_12	4.14	5.71	-	-	-	-	-	-	-	-	-	-	-
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	93519	16	3	83.35	162.53	2636.87	0.04	23.39	32.64	2692.90	506.50
A_16	46.20	47.60	341062	43	3	217.13	423.40	6869.01	0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	93519	11	3	59.54	84.84	1608.73	0.03	13.11	22.44	1644.28	264.38
A_18	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_19	46.20	47.60	119378	15	3	76.00	108.30	2053.55	0.03	16.74	30.60	2100.89	337.49
A_20	147.2	156.40	89757	4	6	35.87	672.53	847.06	0.02	79.36	8.16	934.58	2095.81
A_21	37.80	39.20	-	-	-	-	-	-	-	-	-	-	-
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	-	-	-	-	-	-	-	-	-	-	-
A_24	46.20	47.60	119378	15	3	76.00	108.30	2053.55	0.03	16.74	30.60	2100.89	337.49
A_25	39.60	40.80	138211	20	3	102.65	200.17	3247.51	0.05	28.81	40.80	3317.11	623.79
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	-	-	-	-	-	-	-	-	-	-	-
A_28	220.8	234.60	58645	3	6	15.62	30.47	494.27	0.01	4.38	6.12	504.77	94.94
A_29	86.40	91.80	-	-	-	-	-	-	-	-	-	-	-
A_30	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_31	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40
A_32	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40

Ref	Y initial	Y suggested	Pieces excepted to 2030	Rolls (un)	Saving material				Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
					Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_33	72.43	74.20	89757	0	2	29.50	12.39	119.86	0.01	3.09	0.00	122.95	38.62
A_34	49.50	51.00	119378	2	3	70.93	36.18	820.50	0.03	8.16	4.08	832.74	112.73
A_35	49.50	51.00	119378	1	3	7.09	13.83	224.40	0.00	1.99	2.04	228.43	43.10
A_36	150.4	159.80	72835	0	6	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60	-	-	-	-	-	-	-	-	-	-	-
A_41	33.38	35.56	-	-	-	-	-	-	-	-	-	-	-
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				164.00		2511.18	2368.43	30789.47	0.78	368.69	356.64	31514.80	7380.72

Table 26 - Savings of material, containers, equipment, labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2031

Ref	Y initial	Y suggested	Pieces excepted to 2031	Rolls (un)	Percentage (%)	Saving material Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
A_01	16.04	19.09	-	-	-	-	-	-	-	-	-	-	-
A_02	8.99	10.44	-	-	-	-	-	-	-	-	-	-	-
A_03	8.99	10.44	-	-	-	-	-	-	-	-	-	-	-
A_04	41.14	47.06	-	-	-	-	-	-	-	-	-	-	-
A_05	2.66	2.69	-	-	-	-	-	-	-	-	-	-	-
A_06	35.84	42.34	-	-	-	-	-	-	-	-	-	-	-
A_07	3.04	3.81	-	-	-	-	-	-	-	-	-	-	-
A_08	3.41	3.89	-	-	-	-	-	-	-	-	-	-	-
A_09	6.07	6.61	-	-	-	-	-	-	-	-	-	-	-
A_10	4.10	6.92	-	-	-	-	-	-	-	-	-	-	-
A_11	5.70	6.19	-	-	-	-	-	-	-	-	-	-	-
A_12	4.14	5.71	-	-	-	-	-	-	-	-	-	-	-
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	-	-	-	-	-	-	-	-	-	-	-
A_16	46.20	47.60	341062	43	3	217.12	423.39	6 869.01	0.10	60.93	87.72	7 017.66	1319.42
A_17	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_18	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_19	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_20	147.2	156.40	-	-	-	-	-	-	-	-	-	-	-
A_21	37.80	39.20	-	-	-	-	-	-	-	-	-	-	-
A_22	46.20	47.60	114665	14	3	72.99	104.021	1 972.48	0.03	16.08	28.56	2 017.12	324.16
A_23	39.60	40.80	-	-	-	-	-	-	-	-	-	-	-
A_24	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_25	39.60	40.80	126473	18	3	93.93	183.17	2 971.69	0.04	26.36	36.72	3 034.77	570.813
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	-	-	-	-	-	-	-	-	-	-	-
A_28	220.8	234.60	-	-	-	-	-	-	-	-	-	-	-
A_29	86.40	91.80	-	-	-	-	-	-	-	-	-	-	-
A_30	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_31	48.40	49.87	341062	6	3	207.25	105.70	2 397.44	0.09	23.84	12.24	2 433.52	329.39
A_32	48.40	49.87	341062	6	3	207.25	105.70	2 397.44	0.09	23.84	12.24	2 433.52	329.39

Ref	Y initial	Y suggested	Pieces excepted to 2031	Rolls (un)	Percentage (%)	Saving material Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
A_33	72.43	74.20	-	-	-	-	-	-	-	-	-	-	-
A_34	49.50	51.00	-	-	-	-	-	-	-	-	-	-	-
A_35	49.50	51.00	-	-	-	-	-	-	-	-	-	-	-
A_36	150.4	159.80	72835	0	6	28.48678035	11.96444775	111.74 €	0.01	2.98 €	-	114.72 €	37.28468887
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6	18.09295509	7.599041137	70.97 €	0.01	1.89 €	-	72.86 €	23.6808159
A_40	101.1	103.60	-	-	-	-	-	-	-	-	-	-	-
A_41	33.38	35.56	-	-	-	-	-	-	-	-	-	-	-
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				87.00		845.15	941.55	16 790.77 €	0.38	155.91 €	177.48 €	17 124.17 €	2 934.16

Table 27 - Savings of material, containers, equipment, labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2032

Ref	Y initial	Y suggested	Pieces excepted to 2032	Saving material						Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
				Rolls (un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)		Units	Monetary (€)			
A_01	16.04	19.09	-	-	-	-	-	-		-	-	-	-	-
A_02	8.99	10.44	-	-	-	-	-	-		-	-	-	-	-
A_03	8.99	10.44	-	-	-	-	-	-		-	-	-	-	-
A_04	41.14	47.06	-	-	-	-	-	-		-	-	-	-	-
A_05	2.66	2.69	-	-	-	-	-	-		-	-	-	-	-
A_06	35.84	42.34	-	-	-	-	-	-		-	-	-	-	-
A_07	3.04	3.81	-	-	-	-	-	-		-	-	-	-	-
A_08	3.41	3.89	-	-	-	-	-	-		-	-	-	-	-
A_09	6.07	6.61	-	-	-	-	-	-		-	-	-	-	-
A_10	4.10	6.92	-	-	-	-	-	-		-	-	-	-	-
A_11	5.70	6.19	-	-	-	-	-	-		-	-	-	-	-
A_12	4.14	5.71	-	-	-	-	-	-		-	-	-	-	-
A_13	8.42	9.20	-	-	-	-	-	-		-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-		-	-	-	-	-
A_15	33.00	34.00	-	-	-	-	-	-		-	-	-	-	-
A_16	46.20	47.60	341062	43	3	217.13	423.40	6869.01		0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	-	-	-	-	-	-		-	-	-	-	-
A_18	46.20	47.60	-	-	-	-	-	-		-	-	-	-	-
A_19	46.20	47.60	-	-	-	-	-	-		-	-	-	-	-
A_20	147.2	156.40	-	-	-	-	-	-		-	-	-	-	-
A_21	37.80	39.20	-	-	-	-	-	-		-	-	-	-	-
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48		0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	-	-	-	-	-	-		-	-	-	-	-
A_24	46.20	47.60	-	-	-	-	-	-		-	-	-	-	-
A_25	39.60	40.80	-	-	-	-	-	-		-	-	-	-	-
A_26	48.40	49.87	-	-	-	-	-	-		-	-	-	-	-
A_27	88.00	90.67	-	-	-	-	-	-		-	-	-	-	-
A_28	220.8	234.60	-	-	-	-	-	-		-	-	-	-	-
A_29	86.40	91.80	-	-	-	-	-	-		-	-	-	-	-
A_30	46.20	47.60	-	-	-	-	-	-		-	-	-	-	-
A_31	48.40	49.87	341062	6	3	207.26	105.70	2397.44		0.09	23.84	12.24	2433.52	329.40
A_32	48.40	49.87	341062	6	3	207.26	105.70	2397.44		0.09	23.84	12.24	2433.52	329.40

Ref	Y initial	Y suggested	Pieces excepted to 2032	Rolls (un)	Saving material				Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
					Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_33	72.43	74.20	-	-	-	-	-	-	-	-	-	-	-
A_34	49.50	51.00	-	-	-	-	-	-	-	-	-	-	-
A_35	49.50	51.00	-	-	-	-	-	-	-	-	-	-	-
A_36	150.4	159.80	72835	0	6	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60	-	-	-	-	-	-	-	-	-	-	-
A_41	33.38	35.56	-	-	-	-	-	-	-	-	-	-	-
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				69.00		751.22	758.38	13819.08	0.34	129.56	140.76	14089.40	2363.34

Table 28 - Savings of material, containers, equipment, labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2033

Ref	Y initial	Y suggested	Pieces excepted to 2033	Saving material Rolls (un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
A_01	16.04	19.09	-	-	-	-	-	-	-	-	-	-	-
A_02	8.99	10.44	-	-	-	-	-	-	-	-	-	-	-
A_03	8.99	10.44	-	-	-	-	-	-	-	-	-	-	-
A_04	41.14	47.06	-	-	-	-	-	-	-	-	-	-	-
A_05	2.66	2.69	-	-	-	-	-	-	-	-	-	-	-
A_06	35.84	42.34	-	-	-	-	-	-	-	-	-	-	-
A_07	3.04	3.81	-	-	-	-	-	-	-	-	-	-	-
A_08	3.41	3.89	-	-	-	-	-	-	-	-	-	-	-
A_09	6.07	6.61	-	-	-	-	-	-	-	-	-	-	-
A_10	4.10	6.92	-	-	-	-	-	-	-	-	-	-	-
A_11	5.70	6.19	-	-	-	-	-	-	-	-	-	-	-
A_12	4.14	5.71	-	-	-	-	-	-	-	-	-	-	-
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	-	-	-	-	-	-	-	-	-	-	-
A_16	46.20	47.60	341062	43	3	217.13	423.40	6869.01	0.10	60.93	87.72	7017.66	1319.43
A_17	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_18	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_19	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_20	147.2	156.40	-	-	-	-	-	-	-	-	-	-	-
A_21	37.80	39.20	-	-	-	-	-	-	-	-	-	-	-
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	-	-	-	-	-	-	-	-	-	-	-
A_24	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_25	39.60	40.80	-	-	-	-	-	-	-	-	-	-	-
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	-	-	-	-	-	-	-	-	-	-	-
A_28	220.8	234.60	-	-	-	-	-	-	-	-	-	-	-
A_29	86.40	91.80	-	-	-	-	-	-	-	-	-	-	-
A_30	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_31	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40
A_32	48.40	49.87	341062	6	3	207.26	105.70	2397.44	0.09	23.84	12.24	2433.52	329.40

Ref	Y initial	Y suggested	Pieces excepted to 2033	Saving material					Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
				Rolls (un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_33	72.43	74.20	-	-	-	-	-	-	-	-	-	-	-
A_34	49.50	51.00	-	-	-	-	-	-	-	-	-	-	-
A_35	49.50	51.00	-	-	-	-	-	-	-	-	-	-	-
A_36	150.4	159.80	72835	0	6	28.49	11.96	111.74	0.01	2.98	0.00	114.72	37.28
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	72835	0	6	18.09	7.60	70.97	0.01	1.89	0.00	72.86	23.68
A_40	101.1	103.60											0.00
A_41	33.38	35.56	-	-	-	-	-	-	-	-	-	-	-
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				69.00		751.22	758.38	13819.08	0.34	129.56	140.76	14089.40	2363.34

Table 29 - Savings of material, containers, equipment, labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2034

Ref	Y initial	Y suggested	Pieces excepted to 2034	Rolls (un)	Saving material Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
A_01	16.04	19.09	-	-	-	-	-	-	-	-	-	-	-
A_02	8.99	10.44	-	-	-	-	-	-	-	-	-	-	-
A_03	8.99	10.44	-	-	-	-	-	-	-	-	-	-	-
A_04	41.14	47.06	-	-	-	-	-	-	-	-	-	-	-
A_05	2.66	2.69	-	-	-	-	-	-	-	-	-	-	-
A_06	35.84	42.34	-	-	-	-	-	-	-	-	-	-	-
A_07	3.04	3.81	-	-	-	-	-	-	-	-	-	-	-
A_08	3.41	3.89	-	-	-	-	-	-	-	-	-	-	-
A_09	6.07	6.61	-	-	-	-	-	-	-	-	-	-	-
A_10	4.10	6.92	-	-	-	-	-	-	-	-	-	-	-
A_11	5.70	6.19	-	-	-	-	-	-	-	-	-	-	-
A_12	4.14	5.71	-	-	-	-	-	-	-	-	-	-	-
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	-	-	-	-	-	-	-	-	-	-	-
A_16	46.20	47.60	227063	28	3	144.55	281.88	4573.07	0.07	40.56	57.12	4670.75	878.41
A_17	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_18	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_19	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_20	147.2	156.40	-	-	-	-	-	-	-	-	-	-	-
A_21	37.80	39.20	-	-	-	-	-	-	-	-	-	-	-
A_22	46.20	47.60	114665	14	3	73.00	104.02	1972.48	0.03	16.08	28.56	2017.12	324.16
A_23	39.60	40.80	-	-	-	-	-	-	-	-	-	-	-
A_24	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_25	39.60	40.80	-	-	-	-	-	-	-	-	-	-	-
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	-	-	-	-	-	-	-	-	-	-	-
A_28	220.8	234.60	-	-	-	-	-	-	-	-	-	-	-
A_29	86.40	91.80	-	-	-	-	-	-	-	-	-	-	-
A_30	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_31	48.40	49.87	227063	4	3	137.98	70.37	1596.11	0.06	15.87	8.16	1620.14	219.30
A_32	48.40	49.87	227063	4	3	137.98	70.37	1596.11	0.06	15.87	8.16	1620.14	219.30

Ref	Y initial	Y suggested	Pieces excepted to 2034	Saving material						Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
				Rolls (un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)		Units	Monetary (€)			
A_33	72.43	74.20	-	-	-	-	-	-		-	-	-	-	-
A_34	49.50	51.00	-	-	-	-	-	-		-	-	-	-	-
A_35	49.50	51.00	-	-	-	-	-	-		-	-	-	-	-
A_36	150.4	159.80	48490	0	6	18.97	7.97	74.39		0.01	1.98	0.00	76.37	24.82
A_37	266.7	300.00	-	-	-	-	-	-		-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-		-	-	-	-	-
A_39	236.8	251.60	48490	0	6	12.05	5.06	47.25		0.01	1.26	0.00	48.51	15.77
A_40	101.1	103.60	-	-	-	-	-	-		-	-	-	-	-
A_41	33.38	35.56	-	-	-	-	-	-		-	-	-	-	-
A_42	19.48	20.92	-	-	-	-	-	-		-	-	-	-	-
Total				50.00		524.53	539.67	9859.40		0.24	91.63	102.00	10053.02	1681.75

Table 30 - Savings of material, containers, equipment, labour and total monetary saving and, also, of carbon footprint saving associated with material saved for each reference excepted to 2035

Ref	Y initial	Y suggested	Pieces excepted to 2035	Saving material					Saving containers		Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
				Rolls (un)	Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Units	Monetary (€)			
A_01	16.04	19.09	-	-	-	-	-	-	-	-	-	-	-
A_02	8.99	10.44	-	-	-	-	-	-	-	-	-	-	-
A_03	8.99	10.44	-	-	-	-	-	-	-	-	-	-	-
A_04	41.14	47.06	-	-	-	-	-	-	-	-	-	-	-
A_05	2.66	2.69	-	-	-	-	-	-	-	-	-	-	-
A_06	35.84	42.34	-	-	-	-	-	-	-	-	-	-	-
A_07	3.04	3.81	-	-	-	-	-	-	-	-	-	-	-
A_08	3.41	3.89	-	-	-	-	-	-	-	-	-	-	-
A_09	6.07	6.61	-	-	-	-	-	-	-	-	-	-	-
A_10	4.10	6.92	-	-	-	-	-	-	-	-	-	-	-
A_11	5.70	6.19	-	-	-	-	-	-	-	-	-	-	-
A_12	4.14	5.71	-	-	-	-	-	-	-	-	-	-	-
A_13	8.42	9.20	-	-	-	-	-	-	-	-	-	-	-
A_14	46.20	56.00	-	-	-	-	-	-	-	-	-	-	-
A_15	33.00	34.00	-	-	-	-	-	-	-	-	-	-	-
A_16	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_17	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_18	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_19	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_20	147.2	156.40	-	-	-	-	-	-	-	-	-	-	-
A_21	37.80	39.20	-	-	-	-	-	-	-	-	-	-	-
A_22	46.20	47.60	18535	2	3	11.80	16.81	318.84	0.01	2.60	4.08	325.52	52.40
A_23	39.60	40.80	-	-	-	-	-	-	-	-	-	-	-
A_24	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_25	39.60	40.80	-	-	-	-	-	-	-	-	-	-	-
A_26	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_27	88.00	90.67	-	-	-	-	-	-	-	-	-	-	-
A_28	220.8	234.60	-	-	-	-	-	-	-	-	-	-	-
A_29	86.40	91.80	-	-	-	-	-	-	-	-	-	-	-
A_30	46.20	47.60	-	-	-	-	-	-	-	-	-	-	-
A_31	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-
A_32	48.40	49.87	-	-	-	-	-	-	-	-	-	-	-

Ref	Y initial	Y suggested	Pieces excepted to 2035	Rolls (un)	Saving material Percentage (%)	Area (m^2)	Mass (kg)	Monetary (€)	Saving containers Units	Monetary (€)	Saving in labour and equipment (€)	Total saving (€)	Saving CFP (kg CO_2 eq)
A_33	72.43	74.20	-	-	-	-	-	-	-	-	-	-	-
A_34	49.50	51.00	-	-	-	-	-	-	-	-	-	-	-
A_35	49.50	51.00	-	-	-	-	-	-	-	-	-	-	-
A_36	150.4	159.80	-	-	-	-	-	-	-	-	-	-	-
A_37	266.7	300.00	-	-	-	-	-	-	-	-	-	-	-
A_38	289.3	325.50	-	-	-	-	-	-	-	-	-	-	-
A_39	236.8	251.60	-	-	-	-	-	-	-	-	-	-	-
A_40	101.1	103.60	-	-	-	-	-	-	-	-	-	-	-
A_41	33.38	35.56	-	-	-	-	-	-	-	-	-	-	-
A_42	19.48	20.92	-	-	-	-	-	-	-	-	-	-	-
Total				2.00		11.80	16.81	318.84	0.01	2.60	4.08	325.52	52.40

Appendix V - Material efficiency with the initial and suggested yield and its improvement for each project

Table 31 presents material efficiency with the initial and suggested yield and its improvement for each project.

Table 31 - Material efficiency with the initial and suggested yield and its improvement per project

Reference	ME with the initial Y (%)	ME with the suggested Y (%)	ME improvement (%)
A_01	69.1	82.6	13.4
A_02	54.4	63.3	8.9
A_03	54.4	63.3	8.9
A_04	72.2	82.9	10.6
A_05	67.6	68.4	0.8
A_06	76.5	90.8	14.3
A_07	60.7	76.4	15.7
A_08	49.0	56.0	7.0
A_09	61.8	67.9	6.1
A_10	39.3	66.9	27.6
A_11	63.4	69.5	6.1
A_12	45.4	64.4	19.0
A_13	79.4	87.9	8.5
A_14	87.2	93.7	6.5
A_15	89.8	90.0	0.1
A_16	94.2	94.5	0.3
A_17	96.2	96.5	0.3
A_18	93.2	93.5	0.3
A_19	91.8	92.1	0.3
A_20	93.7	96.8	3.1
A_21	91.8	93.6	1.8
A_22	94.9	95.2	0.3
A_23	95.0	95.2	0.2
A_24	91.8	92.1	0.3
A_25	91.1	91.4	0.2
A_26	97.5	97.8	0.4
A_27	99.0	100.0	1.0
A_28	94.1	97.0	2.9
A_29	93.3	96.1	2.9
A_30	94.2	94.5	0.3
A_31	98.9	99.3	0.4
A_32	98.7	99.1	0.4
A_33	48.0	48.7	0.6
A_34	98.4	98.7	0.4
A_35	98.4	98.5	0.1
A_36	95.4	98.4	3.0
A_37	95.8	99.0	3.1
A_38	95.7	98.8	3.1
A_39	95.8	98.8	3.0
A_40	95.6	96.3	0.7
A_41	66.6	71.5	4.9
A_42	62.5	70.6	5.1

Appendix VI – Carbon Footprint with the initial and suggested yield and its improvement for each project

Table 32 presents CFP with the initial and suggested yield and its improvement for each project presented in percentage.

Table 32 - Carbon Footprint with the initial and the suggested yield and the percentage of its savings

Ref	CFP with the Initial Y (kg CO_2 eq)	CFP with the Suggested Y (kg CO_2 eq)	Saving CFP (%)
A_01	13 710.46	11 522.73	16
A_02	11 450.65	9 860.43	14
A_03	51 601.31	44 435.11	14
A_04	131 306.05	114 791.03	13
A_05	309 026.88	305 580.48	1
A_06	17 694.93	14 978.42	15
A_07	72 362.96	57 738.42	20
A_08	64 511.26	56 551.00	12
A_09	246 307.91	226 185.93	8
A_10	54 057.08	32 015.36	41
A_11	326 843.69	300 947.81	8
A_12	91 616.04	66 437.80	27
A_13	70 223.63	64 269.89	8
A_14	6 143.07	5 068.04	18
A_15	189 856.32	184 272.31	3
A_16	508 828.36	493 862.82	3
A_17	99 100.83	96 186.10	3
A_18	5 711.79	5 543.79	3
A_19	126 502.75	122 782.08	3
A_20	295 484.10	278 102.68	6
A_21	62 302.54	60 077.45	4
A_22	130 476.72	126 639.17	3
A_23	49 271.20	47 822.04	3
A_24	126 502.75	122 782.08	3
A_25	182 164.85	176 807.06	3
A_26	2 682.30	2 603.41	3
A_27	74 395.12	72 207.03	3
A_28	17 793.85	16 747.16	6
A_29	5 869.45	5 524.19	6
A_30	16 001.01	15 530.39	3
A_31	127 029.18	123 293.03	3
A_32	127 029.18	123 293.03	3
A_33	13 450.90	13 130.64	2
A_34	42 256.36	41 013.52	3
A_35	16 156.84	15 681.64	3
A_36	7 189.31	6 766.40	6
A_37	348.68	309.94	11
A_38	321.36	285.66	11
A_39	4 566.18	4 297.58	6
A_40	19 834.61	19 362.36	2
A_41	98 968.55	92 935.32	6
A_42	15 173.74	14 129.27	7