Decarbonize the Production

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Abstract

This dissertation, conducted as part of the Master's degree in Industrial Engineering and Management at the University of Porto, addresses the pressing need for decarbonization in industrial production, specifically within Decathlon Production Portugal (DPP). The primary objective is to develop strategies to enhance energy efficiency and monitor water consumption across various production sectors, contributing to the broader goal of reducing carbon emissions in alignment with Science Based Target initiative (SBTi).

The research is driven by the question: "What is the best strategy to accelerate decarbonization in production from suppliers?" To address this, a multi-phase methodology was employed. Initially, surveys were updated to the latest standards to assess suppliers' compliance with Science Based Target initiative (SBTi). This was followed by verification of survey responses through comprehensive site visits and meetings with suppliers. Based on these assessments, action plans were crafted to enhance energy efficiency scores and ensure suppliers meet their emission reduction targets. A particular focus was placed on prioritizing key suppliers close to achieving maturity, with the aim of meeting a 2024 Key Performance Indicator (KPI) where 25% of the priority list weight would achieve the "Mature" level.

Key findings indicate that systematic, sector-specific improvements can significantly advance the decarbonization efforts within industrial production. The project highlights the importance of collaboration between Decathlon Production Portugal (DPP) and its suppliers, emphasizing the need for continuous monitoring, innovation, and adaptation of strategies to meet long-term sustainability goals. Additionally, the economic benefits derived from enhanced energy efficiency and reduced water consumption underscore the potential for achieving both environmental and operational excellence. Through this comprehensive approach, the dissertation contributes valuable insights into the practical implementation of decarbonization strategies, aligning industrial practices with global environmental targets.

Resumo

Esta dissertação, realizada no âmbito do Mestrado em Engenharia e Gestão Industrial da Universidade do Porto, aborda a necessidade imediata da descarbonização na produção industrial, especificamente no âmbito da Decathlon Production Portugal (DPP). O objetivo principal é desenvolver estratégias para melhorar a eficiência energética e monitorizar o consumo de água em vários sectores de produção, contribuindo para o objetivo mais amplo de reduzir as emissões de carbono em alinhamento com as Science Based Target initiative (SBTi).

A investigação é orientada pela questão: "Qual é a melhor estratégia para acelerar a descarbonização na produção dos fornecedores?" Para responder a esta questão, foi empregue uma metodologia multifásica. Inicialmente, os inquéritos foram actualizados de acordo com as normas mais recentes para avaliar a conformidade dos fornecedores com as SBTi. Seguiu-se a verificação das respostas ao inquérito através de visitas ao local de produção e reuniões com os fornecedores. Com base nestas avaliações, foram elaborados planos de ação para melhorar os resultados da eficiência energética e garantir que os fornecedores cumprem os seus objectivos de redução de emissões. Foi dada especial atenção aos fornecedores próximos de atingir a maturidade, com o objetivo de cumprir o Key Performance Indicator (KPI) para 2024, em que 25% do peso de emissões da lista de fornecedores prioritários tem o nível "Maduro".

As principais conclusões indicam que as melhorias sistemáticas e específicas de cada sector podem fazer avançar significativamente os esforços de descarbonização na produção industrial. O projeto destaca a importância da colaboração entre a DPP e os seus fornecedores, enfatizando a necessidade de monitorização contínua, inovação e adaptação de estratégias para atingir os objectivos de sustentabilidade a longo prazo. Adicionalmente, os benefícios económicos derivados da melhoria da eficiência energética e da redução do consumo de água sublinham o potencial para alcançar a excelência ambiental e operacional. Através desta abordagem abrangente, a dissertação contribui com conhecimentos valiosos para a implementação prática de estratégias de descarbonização, alinhando as práticas industriais com os objectivos ambientais globais.

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This dissertation is a testament to the collective support and encouragement of all these remarkable individuals. Thank you all.

"discipline means being disciplined in all things, especially little things"

Ryan Holiday

Acronyms

ACA Absolute Contraction Approach. 9, 10

BECCS Bioenergy Carbon Capture and Storage. 11

CCUS Carbon Capture Utilization and Storage. 11

CDP Carbon Disclosure Project. 7

CO_2 Carbon Dioxide. xiii, xv, 1, 6, 7, 11, 12, 14, 16, 17, 18, 26, 27, 31, 33, 34, 35

DPP Decathlon Production Portugal. i, iii, 1, 2, 3, 17, 18, 19, 20, 21, 22, 25, 33, 34, 38, 41, 42, 43, 49, 50

EII Energy-Intensive Industries. 7, 11, 12

GCV Gross Calorific Value. 26

GHG Greenhouse Gases. 1, 2, 5, 6, 7, 8, 9, 12, 14, 27, 28

H_2 Hydrogen. 11

IEA International Energy Agency. 14

IoT Internet of Things. 16, 35

IPMVP International Performance Measurement and Verification Protocol. 20, 21, 30

IWWTP Industrial Wastewater Treatment Plant. 28, 36

KPI Key Performance Indicator. i, iii, 3, 21, 30, 32, 33, 41

kWh kilowatt-hour. 26

LPG Liquefied Petroleum Gas. 25, 26

PICA Physical Intensity Convergence Approach. 9, 10

R&D Research and Development. 2, 12

RA Resource Advisor. 18, 21, 22, 25, 26

ROI Return on Investment. 37, 38

SBTi Science Based Target initiative. i, iii, 2, 3, 4, 7, 8, 9, 10, 11, 18, 34, 41

SDA Sectoral Decarbonization Approach. 9, 10

SEU Significant Energy User. 19

SGCIE Sistemas de Gestão dos Consumos Intensivos de Energia. 25, 33, 39

SOP Standard Operation Procedure. 30

UNGC United Nations Global Compact. 7

VCF Volume Correction Factor. 26

VFD Variable Frequency Drive. 38, 39

WMO World Meteorological Organization. 6

WRI World Resources Institute. 7, 14

WWFN World Wide Fund for Nature. 7

ZDHC Zero Discharge of Hazardous Chemicals. 22

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Chapter 1

Introduction

The dissertation "Decarbonize the Production" was successfully developed within the framework of the Master's program in Industrial Engineering and Management at the University of Porto. The development of this work would not have been made possible without the five-month internship at Decathlon Production Portugal in Maia, Portugal. This chapter explains the project's setting, motivation, goals, research approach, and dissertation structure.

1.1 Context

Tackling climate change has become a top issue for corporations, governments, and organizations around the globe. The production sector, encompassing manufacturing, energy, and associated industries, plays a pivotal role in generating a substantial quantity of worldwide Greenhouse Gases (GHG) emissions. Traditional industrial methods emit significant quantities of CO_2 and other GHG into the atmosphere due to their heavy reliance on fossil fuels, depleting natural resources. Decarbonization of production, which entails the reduction or removal of carbon emissions in industrial processes, has emerged as a fundamental strategy to attain worldwide environmental sustainability goals.

According to Medjili et al. (2023), since its first emission in 1760, atmospheric CO_2 levels have increased 1.4 times by 2020. If CO_2 emissions continue unabated, they will rise by 60% by 2100. The combustion of fossil fuels is the principal cause of CO_2 emissions. Aside from that, the bulk of chemical and biological interactions produce CO_2. Global warming is one of the most important environmental challenges caused by CO_2 emissions, affecting all biomes and ecosystems. Therefore there is a need to decarbonize the production to mitigate these challenges. Decarbonizing production entails using cleaner technology, increasing energy efficiency, and transitioning to renewable energy sources. This strategy not only lowers CO_2 emissions, but it also encourages sustainable development and a circular economy (Glenk et al., 2023).

Current international commitments, such as the Paris Agreement, seek to keep global warming well below 2 degrees C above pre-industrial levels, with efforts to restrict the increase to 1.5 degrees Celsius. To meet these goals, fundamental changes in product manufacturing are required, with a focus on transitioning from carbon-intensive to carbon-neutral or carbon-negative processes (European Parliament, 2018). These long-term goals set by numerous countries are evaluated every five years, making this a subject that requires ongoing research, development, and investment.

Decathlon indirectly impacts the environment by gathering raw materials and transforming them into components that emit greenhouse gases. Therefore, Decathlon is committed to decreasing GHG emissions and has partnered with the SBTi on the "Decarbonize the Production" initiative. This study will continue the work done in Carneiro (2023) by looking at the project's third component, reduction, which focuses on energy efficiency and water monitoring projects.

1.2 Decarbonization in Decathlon

Decathlon was founded in 1976 in Lille, France, and has since evolved to become a significant global retailer in the sports business. Decathlon is known for its creativity and commitment to making sports more accessible to everyone. The company's purpose is to provide the fun and benefits of sports to the public in a sustainable manner. Today, the corporation operates in over 70 countries, with over 1,600 locations globally.

Decathlon began with a simple idea: to address the demands of avid sports fans by offering high-quality, low-cost sports equipment. This ambition was fulfilled by establishing its own brands, each dedicated to a distinct sport, allowing for specialization and a thorough understanding of users' requirements. Over the years, Decathlon has increased its global reach, constantly reinventing its product lines and the way it serves sports enthusiasts all over the world.

Decathlon Production Portugal, the production division of Decathlon, was created in 1992, and bicycle production only began many years later, in 1998. Nowadays, DPP manufactures bicycles, helmets, ping pong tables, basketball tables, shoes, and other products using comparable techniques. DPP manages suppliers in Spain through its Portuguese branch. The production office is separated into four teams: industrial processes, human resources, finance, and logistics. Each industrial process has Production Leaders that oversee supplier activity. These Production Leaders are in charge of certain responsibilities such as quality control, supply management, industrialization, and development. Each team is led by a Production Team Manager. The teams include Bike Finished Goods, Bike Components, Plastic and Helmets, Metal, Footwear Industrial Division, and Textile. The Finance and Logistics are cross-functional, providing their expertise to the industrial processes teams as they require.

Decathlon is committed to social responsibility. It works to make sports more accessible by implementing community activities, forming partnerships, and keeping its products affordable. The organization is committed to having a good impact on local communities and using sports to promote inclusion and social change. Decathlon's approach centers on innovation. The company invests in Research and Development (R&D) to create breakthrough solutions that improve athletic performance and safety. Sustainability is another key component of Decathlon's strategy. The company is dedicated to lowering its environmental effect through eco-design projects, promoting sustainable development, and fostering the circular economy in its activities. This project is integrated in this cornerstone that is cross-functional with the different departments, and it requires working with different suppliers from different panels to accomplish Decathlon's sustainability goals.

1.3 Objectives

The primary goal of this research is to promote decarbonization of production by improving energy efficiency and monitoring water consumption in the various production areas covered by DPP, in order to answer the following research question: "What is the best strategy to accelerate decarbonization in production from suppliers?". To achieve that purpose, it was required to check suppliers' compliance with SBTi and the veracity of the answers submitted in the energy efficiency survey by visiting and meeting with the concerned suppliers. Following the assessment, an action plan was developed based on the supplier stage to enhance their energy efficiency score and meet their emissions reduction target. Finally, important suppliers nearing maturity were prioritized to achieve the 2024 Key Performance Indicator (KPI) of 25% priority list weight in the "Mature" level.

1.4 Methodology

The methodology used in this project consisted of four key phases. It began with updating the energy efficiency surveys to the most recent version, followed by analyzing each supplier status and reporting to the appropriate responsible in the DPP, developing a roadmap with future actions for improvement, and finally supervising and reporting on any improvements made by the suppliers.

To grasp Decathlon's commits and ambitions, it was necessary to first get a thorough understanding of SBTi and energy efficiency. This required in-depth understanding of each supplier's condition regarding their SBTi aims and energy efficiency. Because of the survey's update, it was feasible to assess the entire picture of the priority list for the theme.

After the surveys were updated, it was necessary to conduct a thorough examination of each supplier scenario. This analysis provided each supplier with their situation regarding the energy efficiency survey while also highlighting what was necessary in order to go to the next degree of maturity. Following the analysis, a report was prepared to share and discuss with DPP's responsible and the supplier's sustainability management team.

Following the conversation with the suppliers, an action plan was established outlining potential energy efficiency improvements. This roadmap included the activities needed to improve the maturity level, the timescale for doing so, and the ultimate score once the improvements were completed. This roadmap only covers the year 2024, but it includes all of the critical enhancements that a supplier needs to attain the "Mature" level and is expected to be updated annually.

Finally, the four suppliers that are close to reaching the "Mature" level were given priority. It was provided assistance to promote improvements. Establish mutually agreed objectives with each supplier, clearly outlining specific targets and deadlines for attaining increased levels of energy efficiency. When prioritizing suppliers, it was taken into account not only their closeness to leveling up, but also the impact and feasibility of the necessary modifications. Finally, consistently evaluate and modify each strategy, as advancements in technology and energy efficiency regulations progress.

1.5 Dissertation Structure

This dissertation is divided into six chapters, each covering a distinct aspect of the project's development. The first chapter describes both the project and the company, providing an overview of the context and motive. It also highlights the approach employed and the project's objectives. The second chapter provides a theoretical context for the topics covered in this project, including SBTi, energy efficiency, and decarbonization. These topics underscore the importance of decarbonization in manufacturing, which serves as the foundation for the next chapters. Chapter three goes into the framework of the decarbonization effort and presents the basic situation. This chapter explains the suppliers' condition and the technique used to enhance energy efficiency across all providers. The fourth chapter gives a more detailed view into one of the more mature suppliers. This chapter highlights the practices that this supplier is doing, in order to, make it more perceptible the analysis and work done during the internship. The fifth chapter describes the evolution obtained throughout this project regarding energy efficiency and water monitoring. Also, it suggest improvements regarding the specific sector of the supplier and their maturity score. The last chapter discusses the findings, the project's difficulties and limitations, and concludes with recommendations and potential for further research in this field.

Chapter 2

Decarbonize the Production

The objective of this chapter is to present a comprehensive analysis of existing literature pertaining to sustainability, with a specific focus on the process of reducing carbon emissions in production. The essay begins by introducing the notion of decarbonization and providing a framework for carbon emissions. It then presents various methods for reducing carbon emissions in manufacturing and discusses the barriers and issues associated with this topic.

In recent years, experts have been extensively studying decarbonization. As stated by Kanoh (1992), decarbonization can be defined as the gradual reduction in the average quantity of carbon dioxide per unit of primary energy over a period of time. In a subsequent publication, Sun (2005) argued that the term of decarbonization should encompass both social and economic aspects. Decarbonization, as per contemporary definitions, refers to the deliberate efforts made by countries, entities, or individuals to transition towards a low-carbon economy or to decrease their carbon usage (Intergovernmental Panel on Climate Change, 2014).

Decarbonization encompasses several objectives, such as reducing carbon intensity, transforming energy systems, and enhancing dependence on carbon-free or low-carbon energy sources. The primary objective of decarbonization often centers on mitigating GHG emissions, which significantly contribute to the escalation of global temperatures, with the aim of minimizing the impacts of climate change. According to Rissman et al. (2020), it is crucial to achieve net-zero GHG emissions by 2050-2070 in order to restrict global warming to a maximum increase of 2°C. This underscores the significance of decarbonization in the pursuit of climate action. Mitigation activities can effectively decrease GHG emissions and alleviate global warming. Nevertheless, the advantages of decarbonization extend beyond climate concerns; it also positively impacts the environment and economy. Implementing low-carbon technologies can enhance air quality, diminish dependence on fossil fuels, and generate economic prospects. Sofia et al. (2020) conducted a cost-benefit analysis in Italy with the aim of promoting decarbonization by 2030. The study revealed that implementing several mitigation strategies, such as the reduction of air pollution emissions, resulted in substantial improvements in human health.

2.1 The Paris Agreement

The Paris Agreement, a significant event in the field of sustainability, occurred in 2015 with the objective of addressing this issue (Salman et al., 2022). In this specific instance, representatives from 196 nations officially approved the agreement, pledging to decrease their GHG emissions in order to restrict the increase in world average temperature to below 2°C compared to pre-industrial levels, and aiming for a target of 1.5°C. After a span of four years, the United Nations Environment Programme published a report indicating that global emissions had been consistently rising at a rate of around 1.5% year for the previous decade. The primary catalyst for this growing trend is the substantial increase in CO_2 emissions from the energy sector and manufacturing industry, which witnessed a significant 2% expansion in 2018 alone. Therefore, the research emphasizes the vital importance of adopting two essential strategies: reducing carbon emissions in the energy sector and transitioning to electric-powered end-use activities. Nevertheless, the Paris Agreement, regarded as a crucial achievement in tackling worldwide climate change, faces many barriers and limitations that impede its efficacy. A significant concern arises from the non-binding nature of the commitments, as they rely on voluntary adherence without a robust enforcement mechanism. This might possibly undermine the accountability of the participating states. In addition, the targets set by countries to reduce greenhouse gas emissions are widely criticized for being insufficient in achieving the goals of the agreement, which aim to limit global warming to a level significantly below 2°C, with a preference for a rise of only 1.5°C above pre-industrial levels. The inadequate disparity in the assigned obligations between rich and poor nations exacerbates the lack of ambition, overlooking the reality that developed countries have a larger historical carbon footprint. The agreement also lacks stringent transparency standards, so impeding the assessment of countries' actual compliance with their commitments. Moreover, the economic and political challenges linked to the implementation of low-carbon technology could hinder significant progress. This is due to the fact that such transformations need significant financial investment and legal modifications that may not be universally attainable or well-received. These issues highlight the need for enhanced global cooperation and stronger, legally enforceable commitments to really and efficiently tackle climate change (Council on Foreign Relations, 2023)

2.2 Global Carbon Emissions Context

In a 2021 press release, the World Meteorological Organization (WMO) asserted that the impacts of climate change are becoming progressively more evident. Undoubtedly, the increase in GHG levels in the atmosphere has significant ramifications for human well-being and could potentially jeopardize human existence (Chen et al., 2023). The press release from World Resources Institute and World Business Council for Sustainable Development (2004) enumerates several consequences, including heightened occurrence of severe weather phenomena, glacial melting, and the warming and acidification of the oceans. The graph depicted in Figure 2.1 illustrates the upward trend in the global atmospheric concentration of CO_2, a significant greenhouse gas.

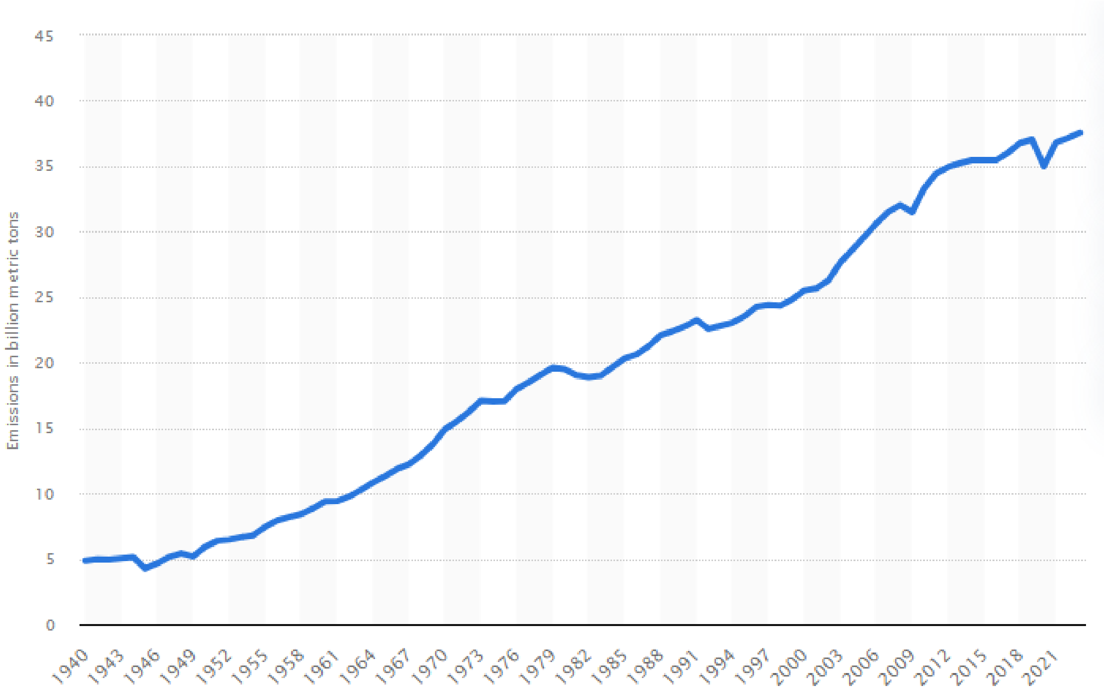

Figure 2.1: CO_2 global emissions

In light of the aforementioned, there has been demand on a worldwide scale to reduce these gases, especially CO_2, which accounts for over 73% of all GHG emissions. Other numerous gases, such as, methane (CH_4), nitrous oxide (N_2O), and even less significant hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6), have the ability to cause the greenhouse effect. By calculating the CO_2 equivalent of each gas (by multiplying it by its global warming potential value of 100), it is possible to determine the individual contribution of each gas to global GHG emissions. The GHG emissions by gas can be classified into four categories: trash, industry, agriculture, forestry, and land use, and energy. The industry sector, encompassing cement and chemicals, is responsible for emitting 5.2% of total emissions. Waste contributes 3.2% to the overall emissions, while agriculture, forestry, and land use account for 18.4%. Energy use accounts for 73.2% of the remaining emissions. The energy sector is comprised of four primary sectors: buildings (17.5%); transportation (16.2%); industries (24.2%); and fugitive emissions and unallocated fuel combustion (13.6%) (Ritchie et al., 2023). According to Wesseling et al. (2017), industrial operations are primarily responsible for these emissions as they transform essential resources, such as raw materials, into necessary items. These production processes necessitate substantial energy consumption due to their elevated intensity, they are also know as Energy-Intensive Industries (EII).

2.3 Science Based Targets

The Science Based Target initiative, established in 2014 by the Carbon Disclosure Project (CDP), the United Nations Global Compact (UNGC), the World Resources Institute (WRI), and the World

Wide Fund for Nature (WWFN), is essential in rallying the commercial sector to take action on climate change. This project promotes the adoption of emission reduction targets by corporations that are based on scientific evidence and are in line with the crucial thresholds defined by the Paris Agreement. The SBTi offers essential help for enterprises to adapt their operational and strategic frameworks in order to effectively achieve these global climate targets. As emphasized by Schweitzer et al. (2023), the initiative plays a crucial role in connecting corporate actions with broader environmental goals, thereby ensuring significant progress in global efforts to reduce carbon emissions and combat climate change. The study also highlights the importance of sector-specific strategies in achieving this impact.

In 2022, there was a significant increase in the usage of SBTis by corporations and financial institutions. 1097 companies got their aims approved, exceeding the combined count of the preceding seven years. Most organizations (76%) with science-based targets publicly shared their progress towards these goals through various means. In 2022, a majority of these organizations (53%) issued thorough reports detailing their progress towards both short-term and long-term goals. In addition, almost 23% of these companies indicated advancement towards at least one particular objective.

The SBTi should encompass the company's scope one emissions, which are direct, and scope two emissions, which are indirect. Scope one emissions refer to the GHG emissions that are generated directly from sources that are owned or controlled by the entity. Scope two emissions encompass indirect emissions, specifically those arising from the purchase of electricity from the grid. Scope three emissions refer to the indirect GHG emissions resulting from a company's activities that originate from sources outside of its ownership or control. Emissions can originate upstream in the supply chain, specifically during the extraction of raw materials for product manufacturing (Schweitzer et al., 2023). If scope three emissions reach 40% of total emissions, they must be included in near-term targets. However, they are always necessary in long-term targets according to Science Based Targets initiative (2023). The emission reduction objectives, whether absolute or intensity-based, must remain in effect for a minimum of five years and a maximum of 10 years after being submitted to the SBTi for validation. As stated in Moreno (2023), it is recommended to establish long-term objectives by the year 2050.

2.3.1 Methodology

The Science Based Target initiative employs a rigorous methodology grounded in climate science to help companies set emissions reduction targets. This method ensures that corporate targets align with what is necessary to limit global warming to well below 2°C above pre-industrial levels, in line with the Paris Agreement goals.

The SBTi methodology begins with the definition of the scope of the emissions to be included in the target. This includes direct emissions from owned or controlled sources (Scope 1), indirect emissions from the generation of purchased electricity consumed by the company (Scope 2), and all other indirect emissions that occur in the company's value chain (Scope 3) (Science Based

Targets initiative, 2023). Companies are required to collect data on their current emissions across these scopes to establish a robust baseline for setting targets.

Once the baseline is established, companies must choose between an absolute-based or intensity-based target. An absolute-based target mandates a straightforward reduction in total GHG emissions over time. In contrast, an intensity-based target specifies reductions relative to a business metric, such as emissions per unit of production or per dollar of revenue.

- **Absolute-Based Targets:** These targets are aligned with the reduction needed globally to keep warming to below 1.5°C or 2°C. They are considered the most scientifically robust form of target within the SBTi framework.

- **Intensity-Based Targets:** These targets must demonstrate that they lead to absolute emission reductions consistent with climate scenarios that limit warming to 1.5°C.

Targets submitted to the SBTi undergo a detailed validation process. This process checks the targets against SBTi criteria to ensure they are in line with current climate science. Validation is conducted by technical experts who assess whether the targets are ambitious enough to meet the Paris Agreement's goals and whether they are measurable and achievable based on the submitted data.

The Science Based Target initiative provides several tools and resources to assist companies in this process. These include the Sectoral Decarbonization Approach (SDA), which provides sector-specific pathways for companies to achieve emissions reductions in line with the 2°C scenario, and the Target Achievement Plan, which helps companies plan actions to achieve their targets.

Companies are required to publicly report their greenhouse gas emissions and progress against their targets annually. Additionally, science-based targets must be recalculated and resubmitted every five years to ensure they remain in line with the latest climate science and data. This structured and scientific approach ensures that the emissions reduction targets set by companies contribute meaningfully to the global effort to mitigate climate change, providing transparency, accountability, and a clear pathway towards a sustainable and low-carbon economy.

2.3.2 Approaches

In their comprehensive analysis, Schweitzer et al. (2023) delineate two distinct strategies that companies can employ to achieve science-based targets that cover both scope one and scope two emissions. These methodologies are known as the Absolute Contraction Approach (ACA) and the Physical Intensity Convergence Approach (PICA). Each approach offers a unique framework for businesses to systematically reduce their carbon footprint in alignment with the rigorous demands of climate science. The ACA focuses on absolute emission reductions over time, thereby ensuring companies contribute to global net-zero objectives through direct decreases in their GHG emissions. Conversely, the PICA centers around reducing the ratio of emissions relative to physical outputs, facilitating companies in becoming more efficient in their emissions per unit of output.

Both strategies are vital in guiding corporations towards sustainable practices that are essential for meeting international climate goals and mitigating the impacts of global warming.

The ACA requires a corporation to decrease its total emissions by a uniform proportion annually. In order to achieve the objective of limiting global warming to 1.5°C, it is necessary to reduce emissions by at least 4.2% per year in the short term. In order to achieve long-term goals, it is necessary to establish a universal strategy that is applicable to all industries. This strategy should aim to reduce missions by a minimum of 90% compared to the base year.

The PICA is a specialized method designed to help firms establish precise emission reduction targets that are tailored to their individual industry. PICA allows enterprises to connect their reduction goals with sectoral trends and possible improvements by considering elements such as emissions, operational activities, and sector-specific characteristics. This approach not only uses global data for comprehensive planning, but it also adjusts to scope three emissions, accommodating different emission profiles within the same industry. In order to achieve a consistent and long-lasting decrease in the intensity of emissions within a specific sector, the use of PICA is crucial. Additionally, the SDA complements PICA by offering a framework for setting immediate and short-term targets based on scientific evidence. This ensures that both strategic and tactical methods are employed to reduce emissions.

Choosing between ACA and PICA depends on several factors, including the specific industry dynamics, regulatory environment, and long-term business goals. ACA might be more suited for established industries in stable markets where reducing overall emissions aligns with both business and environmental objectives. Alternatively, PICA is more suitable for sectors that are growing or located in emerging regions, where there is a likelihood of increased production needs. In such cases, the emphasis should be on reducing emissions intensity rather than absolute emissions.

Essentially, the ACA offers a straightforward approach to achieving complete emission reduction by implementing strict measures that could expedite the shift to low-carbon operations. PICA, meanwhile, offers a pathway that aligns better with continuous improvement and gradual transition, allowing industries to grow responsibly while still contributing to broader climate change mitigation goals. Each approach, therefore, plays a critical role in the diverse landscape of global carbon reduction strategies, tailored to different economic and operational contexts.

2.3.3 Limitations and Challenges

Indeed, certain authors have observed that the existing academic literature pays little attention to the SBTi, with only a handful of research examining its efficacy. Numerous research concentrate on documenting guidelines, exposing a discrepancy between desired goals and the necessary scientific criteria for reducing emissions. As of July 2020, there were limited publications on SBTis, and none provided a complete quantitative evaluation of progress. The SBTi does not have a built-in monitoring system and instead relies on self-reporting (Giesekam et al., 2021).

As stated in Worthington and Lovell (2018) and Carneiro (2023), SBTi have garnered attention and are valuable for policy-making and portfolio-level climate action. However, their efficacy at the individual company level is uncertain. The issue at hand is that SBTi may establish a minimal standard for carbon reduction, allowing certain companies to gain from external factors such as grid decarbonization, rather than making significant efforts to reduce emissions. Real estate organizations, for example, may find it quite simple to achieve their SBTi goals without implementing substantial modifications. Investors with an interest in climate-conscious investments should regard compliance with SBTi as a fundamental criterion. They should also prioritize investments that have well-defined and time-bound strategies for reaching net-zero carbon emissions. In the context of addressing climate change, it is important to view SBTi as a preliminary step rather than a complete solution.

2.4 Solutions for reducing carbon emissions from production

Decarbonizing heavy industries such as iron, steel, cement, and chemicals presents significant challenges due to the limited availability of low-carbon technologies that can satisfy their high energy demands. Hydrogen (H_2) emerges as a promising solution to this dilemma, offering the dual benefits of being an abundant, energy-dense fuel and providing long-duration energy storage capabilities. Despite its potential, the practical implementation of H_2 in industrial decarbonization faces numerous obstacles. These include the technical complexities associated with H_2 isolation and utilization, the high costs of producing low-carbon or zero-carbon H_2, and the current industrial reliance on H_2 derived from fossil fuels. Hydrogen use today is concentrated in oil refining and chemical production, underscoring the need for a shift towards sustainable production methods. Such methods would need to either inherently produce no carbon emissions or integrate effectively with carbon capture technologies (Griffiths et al., 2021).

Nurdiawati and Urban (2021) conducted a recent study that found six crucial techniques for substantially decreasing emissions in Energy-Intensive Industries sectors. The report highlights the importance of technology breakthroughs and critical policy frameworks in achieving this goal. The stated options include demand-side actions, such as promoting reuse and optimizing product designs to minimize the requirement for energy-intensive operations. Additionally, there is a significant emphasis on strengthening energy efficiency, aiming to reduce both emissions and energy usage by improving the operating efficiency of industrial operations. Another crucial approach entails substituting conventional fossil fuels and feedstocks with low-carbon alternatives such as biomass and renewable hydrogen. In addition, the utilization of low-carbon energy sources to electrify industrial processes aids in lowering reliance on fossil fuels, so contributing to a decrease in emissions. Carbon Capture Utilization and Storage (CCUS) technologies are crucial in capturing carbon emissions and preventing them from entering the environment. These technologies either store the captured carbon or repurposed it for other uses. The dual functionality of negative emission technologies, such as Bioenergy Carbon Capture and Storage (BECCS), is emphasized due to its ability to both extract CO_2 from the atmosphere and decrease emissions.

Multiple studies, including those referenced by Couchy (2023), have highlighted the significance of these measures in attaining a completely decarbonized industrial sector. These studies specifically underline the crucial function of energy efficiency. Emphasizing energy efficiency is in line with the strategic objectives of established organizations, providing them with cost savings and pollution reduction without jeopardizing their revenue-generating operations. Nevertheless, it is imperative to acknowledge that enhancing efficiency alone will not be adequate to accomplish the requisite substantial reductions in emissions.

2.5 Barriers for Decarbonization

According to Oberthür et al. (2021), the deep decarbonization of EIIs is hindered by six main barriers and challenges. The first significant barrier is the lack of mature low-CO_2 technologies. Most technologies capable of eliminating GHG emissions from EIIs are still in the early stages of development, with existing technologies offering only limited decarbonization potential. Consequently, there is a substantial need for further R&D, particularly in areas like electrification, carbon capture, and the use of non-fossil fuel feedstocks.

Another critical challenge is the limited investment in research and development within EIIs, which is relatively low compared to other sectors. This scarcity of funding makes it particularly difficult for smaller new entrants to access markets and secure financing for innovative solutions. Additionally, the high capital expenditures and long investment cycles required for EIIs facilities pose significant barriers. These industries require substantial upfront capital investment and have long life cycles, leading to carbon lock-in and exposing new, unproven technologies to high financial risks during demonstration and commercialization phases.

Operational costs and competitiveness also present major challenges. Low-carbon technologies typically incur higher operational costs, particularly during development stages, which can adversely affect the competitiveness of EIIs products in global markets. Without supportive policies, these increased costs are often not transferable to consumers, further complicating financial viability.

The complexity of global value chains also acts as a barrier. As globalization has intertwined these chains, managing global competition and internationalizing efforts to track and control product end use becomes challenging. This complexity also impedes recycling and upcycling efforts, further complicated by labor-intensive product designs.

Lastly, the absence of adequate policy frameworks significantly restricts EII decarbonization efforts. Effective policy mechanisms, such as R&D support, subsidies, carbon pricing, and product standards, are urgently needed. Additionally, given the global nature of EIIs, international cooperation is essential to prevent carbon leakage and ensure the effectiveness of these policies, highlighting the necessity for a concerted global approach to overcome these extensive barriers and challenges.

Ghaforian Masodzadeh et al. (2022) specifies that energy efficiency faces a unique set of challenges that can be broadly categorized into economic and non-economic difficulties. Each category has a distinct impact on the acceptance and execution of energy-efficient technology and practices, which in turn affects the overall efficiency and practicality of energy-saving measures.

Table 2.1: Energy Efficiency Non-economic Barriers

Type	Barriers
Organizational	Slim organization Incomplete market Imperfect competition
Information	Imperfect information Asymmetric information Split incentives
Technical	Safety and security considerations
Policy	Regulatory challenges Ineffective policy frameworks
Behavioral	Resistance to change Lack of motivation

To fully harness the potential of energy efficiency measures and achieve environmental goals while ensuring economic stability, it is essential to address these difficulties in a holistic manner.

Economic barriers result from the disparity between the potential of energy efficiency technology and its actual implementation on-site. This frequently arises due to limitations in operations, obsolete infrastructure, and a lack of synchronization between the capabilities of the technology and the specific demands or circumstances of the operational setting. Uncertainties surrounding future energy expenses and the possible benefits of investing in energy efficiency can discourage companies from allocating funds. In smaller or financially vulnerable companies, obtaining the necessary finance for first investments in energy efficiency might pose major challenges. These occur when the market fails to efficiently allocate resources, typically disregarding external factors such as environmental implications, which are vital in the context of energy efficiency. Hidden costs, such as those associated with training, maintenance, or interruptions during installation, might contribute to the overall expenditure of energy-efficient projects.

Table 2.1 demonstrates that non-economic barriers consist of organizational, informational, technical, policy-related, and behavioral challenges. Energy efficiency improvements might be hindered by organizational factors such as insufficient organizational capability or market frameworks that do not promote competition. Issues such as insufficient data on the advantages and drawbacks of energy efficiency, unequal access to information among the parties involved, and conflicts of interest caused by misaligned incentives. The safety and reliability of new technologies can be a major obstacle to their acceptance, particularly in risk-averse industries like shipping. Regulatory frameworks that are ineffective or not supportive might hinder the progress and financial backing of energy-efficient technologies. Behavioral barriers encompass obstacles such as opposition to adopting new methods or technology, influenced by cultural factors, lack of drive, or unwillingness to modify current routines (Alyami, 2015).

2.6 Advantages of Decarbonization

Decarbonizing production processes is critical for tackling the global climate crisis since it dramatically reduces GHG emissions. The transition from traditional energy sources that rely largely on fossil fuels to low-carbon or renewable alternatives significantly reduces CO_2 emissions and other pollutants. This reduction is critical for stabilizing global temperatures, which, according to the Intergovernmental Panel on Climate Change (2018), must be kept to a 1.5°C rise above pre-industrial levels to avoid the most severe effects of climate change. Beyond mitigating global warming, decarbonization also enhances air quality. Traditional production methods generate not just CO_2, but also sulfur dioxide (SO_2), nitrogen oxides (NOx), and particulate matter, all of which contribute to severe air pollution. These pollutants have been related to a variety of health concerns, including respiratory and cardiovascular disorders. Industries can drastically reduce emissions of these dangerous pollutants by implementing cleaner technology and energy sources, resulting in improved public health results.

This process also creates enormous economic potential by enabling the adoption of new technologies and energy efficiency improvements. The International Energy Agency (IEA) examines the long-term economic benefits of investing in sustainable energy technology, which not only lower operational costs but also improve energy security by reducing reliance on imported fuels (International Energy Agency, 2023). According to Beccarello and Foggia (2023), the transition to a low-carbon economy will need considerable investments and is projected to have profound social consequences, including job creation and economic growth through the development of low-carbon technology and sectors. The policy scenario expects an increase in production and value added, emphasizing the economic advantages of shifting to a greener economy.

The study on the decarbonization of natural gas emphasizes the enormous industry-specific benefits of incorporating renewable hydrogen into existing natural gas infrastructures. This shift provides a feasible way to reduce carbon emissions by replacing regular natural gas with hydrogen, which releases only water vapor when combusted. Such a change not only helps to reduce GHG emissions, but also reduces dependency on foreign fuels, so improving national energy security. Technological developments are vital for this shift since they require the development of new hydrogen generation, storage, and injection methods (Khatiwada et al., 2022).

Organizations such as the WRI emphasize the importance of strong legislative frameworks in accelerating the transition to green technologies. These frameworks may include restrictions to minimize harmful emissions, incentives to use renewable energy, and subsidies for green technology research and development. By establishing clear guidelines and providing financial incentives, these policies ensure that businesses are both motivated and supported in their efforts to invest in sustainability. This faster acceptance of green technologies enables industry to transition away from environmentally harmful energy sources and processes, such as fossil fuels, and toward cleaner alternatives like solar and wind energy or hydrogen fuel. These policy-driven initiatives also stimulate corporate investment in sustainability. Governments may provide tax breaks to companies that lower their carbon footprints or penalize those that fail to satisfy environmental

Table 2.2: Benefits of Energy Efficiency

Level	Benefits
Individual	Health and well being impacts Poverty Alleviation Increased disposable income
Sectoral	Industrial productivity and competitiveness Energy provider and infrastructure benefits Increased asset values
National	Job creation Reduced energy related public expenditures Energy security Macroeconomic effects
International	Reduced GHG emissions Moderating energy prices Natural resource management Development goals

requirements. Such policies not only encourage businesses to reduce their environmental impact, but also hold them accountable for their activities.

2.6.1 Energy Efficiency

Efficient energy utilization in buildings improves indoor air quality, reducing respiratory and other health problems for individuals. In terms of economic alleviation, energy efficiency is especially useful for low-income households since it lowers their energy costs, alleviating energy poverty and allowing them to dedicate funds to other vital needs.

Economically, energy efficiency measures increase consumer disposable income while decreasing company operating expenses, so stimulating broader economic activity and improving local economies. In the industrial sector, these methods result in significant cost savings, reduced resource waste, and increased overall competitiveness. Furthermore, investment in energy-efficient technologies creates job prospects.

From an environmental aspect, increasing energy efficiency reduces the demand for fossil fuel-based energy generation, cutting greenhouse gas emissions and other pollutants. This leads to improved environmental results and helps to battle climate change. Additionally, energy efficiency improves national energy security by lowering overall energy consumption, reducing reliance on foreign fuels. Furthermore, energy efficiency can result in significant savings in public expenditures, particularly where the government subsidizes energy expenses. By reducing the need for these subsidies, governments can improve fiscal health and reallocate resources to other key areas of growth.

These benefits apply at several levels, including individual, household, and enterprise; sectoral: industrial, transportation, residential, and commercial; national; and international. Table 2.2 illustrates how these benefits can be organized.

2.6.2 Water Reduction

Water scarcity is a major global concern, and lowering water usage increases resilience to this challenge. Effective water monitoring improves energy efficiency, which is crucial for reducing carbon emissions. The study by Peng et al. (2023) found that energy substitution and efficiency improvements in China's electricity sector significantly reduced water use and CO_2 emissions. Reducing water consumption naturally reduces the amount of wastewater that requires treatment, an energy-intensive process.

Moreover, efficient water use enhances the supply chain by transferring electricity from low to high water intensity locations, resulting in significant water savings. This optimization promotes innovation by encouraging the use of modern technologies, such as smart sensors, for real-time water usage data analytics, thereby increasing efficiency and sustainability. Effective water monitoring guarantees regulatory compliance and can result in significant cost savings (HydroPoint Data Systems, Inc., 2023). Highlighting that energy substitution and efficiency improvements resulted in water-saving co-benefits contributes to a reduction in overall environmental impact and operating costs.

The integration of advanced water monitoring systems, such as Internet of Things (IoT) devices and automated control systems, can provide granular insights into water usage patterns. These technologies enable industries to identify leaks, inefficiencies, and opportunities for water reuse, which can drastically reduce water wastage. For instance, smart irrigation systems in agriculture can optimize water use based on soil moisture data, weather forecasts, and plant water needs, thereby conserving water while maintaining crop yields.

Furthermore, water and energy are often interdependent in many industrial processes. In power generation, for example, significant amounts of water are used for cooling purposes. By improving the efficiency of cooling systems and adopting alternative cooling technologies, power plants can reduce their water footprint. This not only conserves water but also enhances the plant's operational efficiency and reduces its environmental impact.

Water conservation efforts also play a pivotal role in mitigating climate change. The energy required to treat and transport water is significant, and reducing water usage can thus lead to substantial energy savings. This connection between water and energy use is often referred to as the water-energy nexus. Recent research has highlighted the importance of addressing this nexus to achieve sustainability goals. For instance, Deng et al. (2023) discusses how ecosystem services can be optimized to enhance both water and energy sustainability. By leveraging natural processes, such as wetland restoration, to improve water quality and availability, we can reduce the reliance on energy-intensive water treatment technologies.

Chapter 3

Problem Description

The vision of Decathlon Production Portugal as "a driving force and a beacon of light for a sustainable future" profoundly influences its strategic decisions and operational ethos. This vision manifests in various impactful ways: DPP acts as a catalyst for change, pioneering new paths and fostering collaboration to magnify its impact within and beyond its organizational boundaries. As a beacon of light, the company leads by example, inspiring others through its commitment to transparency, trust, courage, and innovation. DPP's dedication to a sustainable future is evident in its efforts to create shared value for society by promoting health and wellness through sports, supporting community initiatives for inclusivity and equality, and integrating sustainable practices across all facets of its operations. Overall, DPP is reshaping the consumer experience from mere product interaction to engaging in practices that contribute to a sustainable lifestyle.

DPP's product life cycle, which extends from design to disposal, involves raw material extraction, component transformation, final product assembly, transit to warehouses, and eventual sale. After use, products are recycled, repaired, burnt, or disposed of in landfills. Each stage of this process increases the company's environmental impact, particularly its carbon footprint. In terms of footprint, the initial stage, extracting raw materials and producing them, has the greatest impact. As a result, the company's principal focus is on decarbonizing its production by eco-designing products with sustainable raw materials and improving energy transformation efficiency throughout production.

DPP announced the "Decarbonize the Production" project in 2019 to reduce CO_2 emissions among its suppliers. The Figure 3.1, shows how the project is divided.

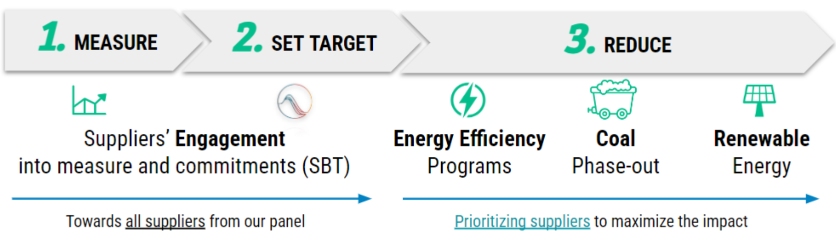

Figure 3.1: Decarbonize Production

Each phase required certain actions and objectives. During Phase 1, suppliers were obligated to track their CO_2 emissions. Schneider Electric provided software called Resource Advisor (RA) to record their consumption data, which was subsequently utilized to determine the CO_2 levels. During Phase 2, the data quality rate was employed to oversee the process and establish goals. Suppliers were requested to enroll in the SBTi program to ensure that DPP could have assurance that they would undertake necessary measures to reduce emissions. Throughout this phase, various metrics were employed to oversee the process, including the validation rate of SBTis, the percentage of trajectory validations, and the percentage of achieved gap compared to the commitment. Phase 3 seeks to reduce emissions by implementing energy efficiency measures, phasing out coal (which is no longer relevant in Portugal and Spain), and transitioning to renewable energy sources. The maturity level and deployment percentages of the maturity survey have been selected as indicators to monitor this phase.

This project was conducted during Phase 3 of the "Decarbonize the Production". DPP undertook an energy efficiency audit in order to decrease emissions and achieve its SBTi. This survey offered the company a comprehensive assessment of the supplier's degree of maturity and identified areas where operational efficiency could be enhanced. As indicated in Table 3.1, the survey was implemented based on their priority list, with 17 providers identified as their main emitters. The company places a high priority on reducing carbon emissions by working closely with suppliers that have the most influence on the issue. These include suppliers that have the highest emissions. The roster of eligible suppliers in Portugal comprised seventeen companies spanning the footwear, textile, plastic, metal component, and bicycle assembly sectors. Table 3.1 presents statistics on the activities and emissions of eligible providers, derived from information recorded in RA, namely from the base year of 2022. Due to confidentiality reasons, the names of the suppliers have not been disclosed.

3.1 Energy Efficiency

This project aims to demonstrate to suppliers that energy efficiency means consuming less energy to complete the same tasks, therefore minimizing energy waste. Environmentally, it lessens the demand for energy, resulting in decreased greenhouse gas emissions from power plants, particularly those that use fossil fuels. This is critical for achieving global climate goals like those established in the Science Based Target initiative. Energy efficiency minimizes energy expenses, resulting in financial benefits for the industry. These savings can also provide other economic advantages, such as employment development.

3.1.1 Energy Efficiency Survey

In order to assess the degree of maturity in energy efficiency, the company determined that it was imperative to conduct an energy efficiency study for the chosen suppliers and thereafter develop a comprehensive action plan to enhance energy efficiency. At the beginning of the internship, the company had previously administered a survey to assess the degree of advancement in energy

Table 3.1: Suppliers Priority List

Supplier	**Process**	**CO_2 Total Tons for DPP**	**% of total emissions**
A	BIKES	1,998.0	26.4
B	BIKES	1,970.0	26.1
C	HELMET	989.0	13.1
D	PLASTIC COMPOSITE	607.0	8.0
E	TEXTILE	358.0	4.7
F	BIKES	286.0	3.8
G	PACKAGING	285.0	3.8
H	FOOTWEAR	179.0	2.4
I	METAL	138.0	1.8
J	PLASTIC COMPOSITE	137.0	1.8
K	METAL	129.0	1.7
L	BIKES	127.0	1.7
M	FOOTWEAR	114.0	1.5
N	FOOTWEAR	102.0	1.4
O	BIKES	83.0	1.1
P	FOOTWEAR	37.0	0.5
Q	WOVEN	20.0	0.3

efficiency among suppliers, which had been communicated and fulfilled by the suppliers (Carneiro, 2023). The survey is structured into the following parts:

1. Basic Information of the Company
2. Policy Planning and Management
3. Data Measurement and Management
4. Energy Intervention Investments
5. Measurement and Verification

With the exception of Part 1 (P1), the survey consists of multiple-choice questions, simplifying the process of completing the survey and allowing for the obvious classification and comparison of each source. In Part 1, the suppliers are required to provide essential details such their name, address, country, and contact information, therefore there is no score in this part. Additionally, they must disclose their energy sources, Significant Energy User (SEU), certification, and primary operational procedures.

In Part 2 (P2) , "Policy, Planning, and Management," the questions revolve around the supplier's long-term commitment and plans to reduce energy and water use, energy efficiency investments to gather data and verify savings, and the availability of human and financial resources. Part 3 (P3), "Data Measurement and Management," is more focused if the provider conducted an internal energy assessment and had the ability to collect production and energy consumption data on a regular basis in order to cross-check the data and determine their energy intensity at all

Table 3.2: Survey Parts Levels

Part	Weight	Maturity Level	Score
		Mature	[55;71]
2	50%	Progressing	]36;55[
		Not Mature	[0;36]
		Mature	[45;79]
3	25%	Progressing	]20;45[
		Not Mature	[0;20]
		Mature	[28;33]
4	15%	Progressing	]10;28[
		Not Mature	[0;10]
		Mature	[40;45]
5	10%	Progressing	]10;40[
		Not Mature	[0;10]

times. The capacity to constantly monitor energy intensity allows for the detection of deviations in production and energy consumption and the correction of them so that the least amount of money and energy is spent. The supplier process is covered in Part 4 (P4), "Energy Intervention Investments". Textile, footwear, dyeing, plastic, metal, and other are the processing options offered. Each supplier responds to only one of these areas, which pertains to their processes and potential investments in their specialized machines. Finally, Part 5 (P5), "Measurement and Verification," discusses the final step that the supplier must do, which is to conduct a financial feasibility study for their energy efficiency investments and, once implemented, compute their monthly energy savings to demonstrate return on investment. DPP prefers and recommends that suppliers comply with the International Performance Measurement and Verification Protocol (IPMVP) when calculating their energy savings due to investments. Table 3.2 shows that the ultimate maturity score includes distinct values and weights for each of these parts. The final maturity score is provided by equation 3.1.

$$\begin{aligned} \text{Total Points} = \text{P2 Points} \times 0.50 + \text{P3 Points} \times 0.25 \\ + \text{P4 Points} \times 0.15 + \text{P5 Points} \times 0.10 \end{aligned} \tag{3.1}$$

In terms of energy efficiency, the assessment classifies suppliers as "Not Mature", "Progressing", or "Mature". A provider rated "Not Mature," with fewer than 25 total points, typically lacks an energy efficiency policy and does not map its energy usage. Suppliers in the "Progressing" category, defined as having more than 25 points but less than 50,6 total points, may have a policy and energy maps but may not invest significantly in energy efficiency, allowing room for progress. Suppliers rated "Mature" have already implemented energy-saving measures, collect current data on their production and energy consumption. This suppliers set a good example for others and make for convincing arguments of how much a supplier can save by investing in energy efficiency.

3.1.2 Energy Efficiency Roadmap

After the assessment of the survey, a roadmap is discussed with a supplier in order to improve their score and become more efficient. Depending on the supplier level, "Not Mature", "Progressing", and "Mature", the roadmap focuses on the supplier's next step, being this, "On-boarding", "Optimization", and "Reporting", respectively.

Suppliers at the "On-boarding" stage lack a commitment to energy efficiency, and to lowering water and energy consumption. To improve this suppliers, first, visit with the supplier to stress the importance of energy efficiency programs and investments in meeting DPP's decarbonization targets while lowering energy prices. After that, the supplier must conduct an internal energy analysis, typically with the assistance of an external organization, to better understand their energy consumption and areas for improvement. Following that, they must develop a water and energy reduction plan, as well as an energy efficiency commitment with long-term goals, and make accessible money and human resources to collect data and verify savings. This way, the supplier is able to achieve the "Progressing" level.

In the "Optimization" stage, suppliers have already committed to energy efficiency investments and pretend to or already collect data at the process level (level 2). In order to optimize, suppliers must begin collecting daily data from each machine (level 3) and cross-referencing it with production data to determine energy intensity. The energy intensity enables the supplier to address errors and leaks more quickly while saving energy and gas. After they have the energy intensity tool and a baseline year, they must develop energy KPIs in order to have a strong plan for reducing their energy intensity in the next years. With this improvement, it is able to determine the energy saved and thus the return on investment using IPMVP, consequently achieve the "Mature" level.

Finally, suppliers in the "Reporting" stage are already collecting energy intensity data and can save money and energy while maintaining the same level of production. At this point, suppliers should maintain their commitment to reducing emissions and keep DPP informed by registering them on RA. It is also recommended that they continue to evaluate their computers to determine whether an upgrade or replacement would be more efficient. This suppliers are intended to become benchmarks to the other suppliers and helping them through their good practices.

3.2 Water Monitoring

The first stage in water monitoring in production environments is the diligent collecting of data on how much water each supplier uses. This fundamental phase is critical because it creates a baseline against which all later analyses and improvements are evaluated. Companies that precisely analyze water usage across several providers can identify critical areas where water consumption can be optimized, monitor compliance with environmental standards, and evaluate their suppliers' sustainability policies.

This data collection includes not only the amount of water used, but also the reasons for its use, such as manufacturing operations, cooling, sanitation, or other operational requirements.

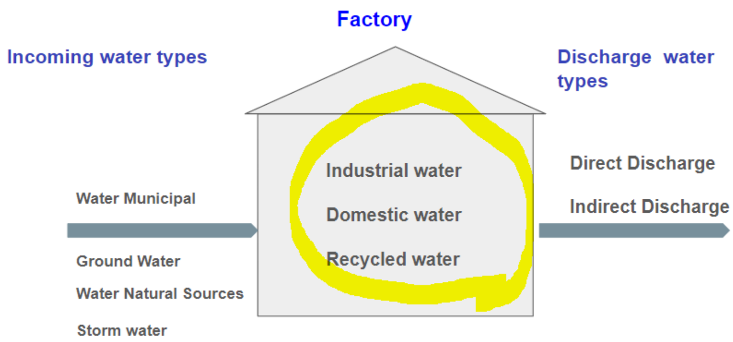

Figure 3.2: Water Monitoring

Advanced metering technologies and monitoring systems are frequently used to enable accurate and continuous measurement of water flow, resulting in more dependable and comprehensive data sets.

Companies that gain a comprehensive picture of water usage trends are better able to execute targeted conservation initiatives, negotiate more educated water management policies with suppliers, and promote more sustainable usage practices throughout their supply chain. Furthermore, this data is an important component in reporting for company sustainability evaluations and public disclosures about environmental effect, highlighting the significance of this first step in the larger context of environmental stewardship and regulatory compliance.

According to Zero Discharge of Hazardous Chemicals (ZDHC), DPP has prepared a priority list for water monitoring and, as a result, water reduction. Suppliers are classified as concerned with water usage if they consume more than 15 m^3 per day. To monitor water consumption, each supplier is asked to register it in RA. The data should be recorded in three categories: domestic use, which includes all water used outside of the manufacturing process, such as for day-to-day activities; industrial water, which includes all water used in the manufacturing process; and recycled, which includes all water recycled and reintroduced into the water system. The figure 3.2 illustrates how each supply should register the water.

DPP is concerned with data quality, so each supplier must register their water usage in the appropriate field. Out of 15 suppliers, only 9 suppliers (60%) have registered their water consumption on RA. Table 3.3 lists the suppliers who track water use and which ones provide high-quality data. As can be seen, 4 of those suppliers do not record data in the appropriate fields: home use, industrial water, and recycled water.

The purpose of this initiative is to ensure that providers record their consumption with accurate data. To reach this goal, it is necessary to educate providers on the necessity of water monitoring and how to correctly register it. After collecting high-quality data, it is possible to monitor and develop an effective plan to reduce water usage based on each field where water is utilized.

Table 3.3: Water Monitoring Priority List

Supplier	**Registering**	**Quality Data**
A	Yes	Good
B	Yes	Bad
C	Yes	Bad
D	No	
F	Yes	Good
G	No	
H	No	
K	No	
L	Yes	Good
M	No	
O	No	
P	Yes	Bad
Q	Yes	Good
R	Yes	Good
S	Yes	Bad

Chapter 4

Case Study

This chapter provides an in-depth analysis of Supplier F, which is highlighted in Table 3.1. Supplier F was chosen for its outstanding performance in recent energy efficiency evaluations and its forward-thinking approach to sustainable water management. Supplier F distinguishes itself by nearing the mature level in energy efficiency, showcasing its commitment to implementing effective energy-saving measures and technologies within its operations. The expertise in energy management not only improves its ability to continue operations but also establishes it as a prominent model within its industry.

4.1 Energy Consumption

Under the Sistemas de Gestão dos Consumos Intensivos de Energia (SGCIE), Supplier F follows a Rationalization Plan aimed at reducing energy intensity and specific consumption. This supplier is under SGCIE because it is an energy intensive user, more than 500 equivalent tons of petroleum, according to the portuguese law. The plan includes regular monitoring and optimization of energy use across all operations. In 2022, Supplier F achieved a significant reduction in energy intensity, lowering it by 28% compared to the previous year, and also reduced specific energy consumption per piece produced by 29%. These improvements were primarily driven by optimizing production processes and increasing operational efficiency. While it is not yet possible to obtain the exact production numbers for 2023, Supplier F continues to adhere to the SGCIE guidelines, which mandate a minimum energy intensity reduction of 4%. This commitment ensures ongoing efforts to enhance energy efficiency, demonstrating Supplier F's dedication to sustainable manufacturing practices.

Supplier F utilizes a total of five energy sources, including green electricity from the grid, solar panel electricity, diesel, gasoline, and Liquefied Petroleum Gas (LPG). Over the course of the manufacturing process, electricity and LPG are utilized, whereas diesel and gasoline are utilized for the transportation of both staff and products. The tracking platform offered by DPP, RA, granted access to the consumption data of the five energy sources in 2023. However, in order to determine the most utilized energy type, it was imperative to convert the energy from various sources into

Table 4.1: Energy Consumed

Energy Source	**GCV**	**VCF**	**Volume**	**Energy Consumed**
Diesel	10,200.0	1.0	14.0	145,190.0
Gasoline	9,691.0	1.0	13.4	129,820.0
Liquefied Petroleum Gas	24.4	1.1	127.8	3,330.0

a standardized unit, namely kilowatt-hour (kWh). Therefore, it was necessary to convert LPG, natural gas, and diesel, which are measured in m^3, into kWh. The Gross Calorific Value (GCV) utilized in this calculation were obtained from the sources Ministério da Economia e da Inovação - Direcção-Geral de Energia e Geologia (2008) and Portgás (2024). The Volume Correction Factor (VCF) of each energy source was provided by Resource Advisor. This conversion allows to m^3 of diesel, gasoline and LPG, to be converted to kWh. The total energy consumption of each energy source is calculated using the following equation 4.1:

$$\text{Energy Consumed (kWh)} = \text{Volume (m}^3\text{)} \times \text{VCF} \times \text{GCV} \tag{4.1}$$

The table 4.1 details each energy source GCV, VCF, volume and energy consumed.

Following the completion of the conversion, it is possible to examine the various consumption on the same unit, as shown in figure 4.1. It can be inferred that the use of diesel and gasoline is lower in comparison to electricity, whereas LPG has negligible values. Being electricity their main energy source Supplier F's future goals include doubling its installed photovoltaic capacity to increase energy self-sufficiency and continuing to explore new energy-efficient technologies and processes. The company is committed to maintaining a high proportion of renewable energy in its energy mix and continuously improving energy efficiency.

4.2 GHG Emissions

Despite the smaller levels, it is essential to determine which source had the most significant influence on the supplier's CO_2 emissions. A recent conversion was conducted to compare various energy sources in terms of their respective CO_2 emissions, measured in metric tons. Table 4.2 displays the various emissions categorized by source, as reported in the RA.

Table 4.2: Emissions by Source

Energy Source	**Emissions (metric tons)**
Diesel	42.0
Gasoline	38.0
Liquefied Petroleum Gas	0.8
Solar Panels	0.0
Green electricity	0.0

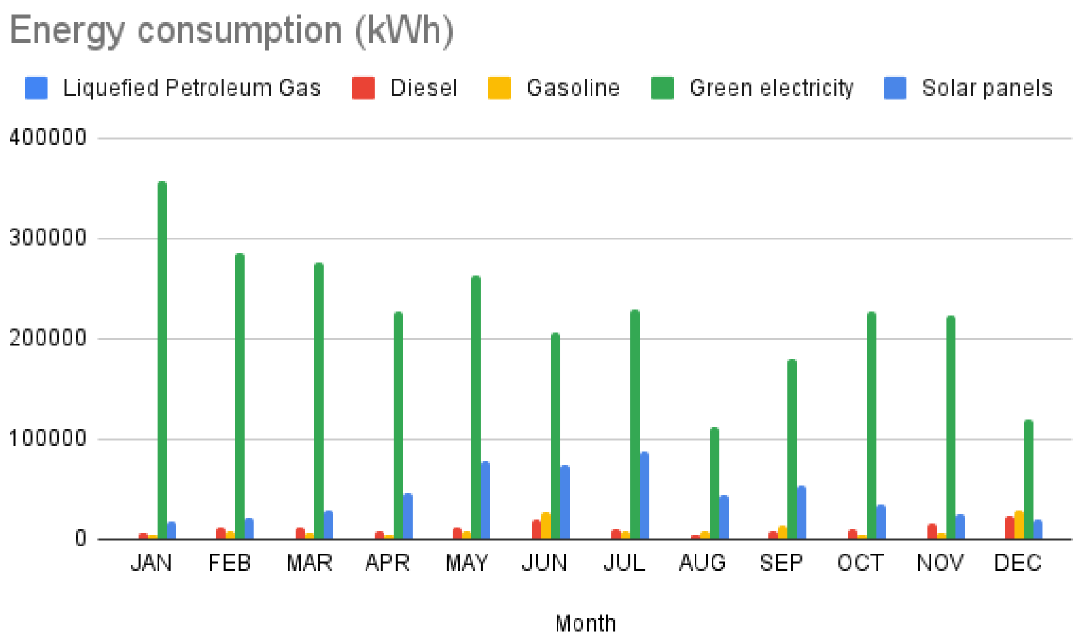

Figure 4.1: Supplier H energy Consumed by source in 2023

Thus, it can be deduced that diesel and gasoline, despite not being the most widely employed energy source, exert the greatest impact on the carbon footprint, specifically by emitting the highest quantity of CO_2 in metric tons.

Supplier F has implemented several initiatives to reduce GHG emissions:

- Electric Charging Stations: The installation of eight electric charging stations at Supplier F's facilities encourages employees to use electric vehicles, reducing emissions from commuting.

- Eco-friendly Production: The adoption of eco-friendly solvents and paints, and improvements in production processes, have reduced emissions associated with these activities. For instance, changes in the painting process have led to more efficient use of materials and lower emissions.

- Digitalization: Efforts to digitize processes and communications have reduced the use of paper and associated emissions. Internal and external communications, invoices, and employee documentation are now primarily digital, using certified paper when necessary.

- Product Innovations: The introduction of the crankset innovation, which allows for the separation and independent replacement of components, reduces waste and emissions associated with the end-of-life disposal of bicycle parts.

Supplier F aims to continue reducing its carbon footprint through increased use of renewable energy, further improvements in production efficiency, and comprehensive GHG emissions accounting and reduction strategies. The company plans to complete a full GHG inventory for all scopes by 2023 and set ambitious targets for emission reductions.

4.3 Water Consumption

Supplier F's water consumption strategy emphasizes efficiency and sustainability. The company sources water from both an artesian borehole and the municipal supply network, using each source for specific applications. Borehole water primarily supports industrial processes, such as machine cooling, vibration, and wastewater treatment, while municipal water is used in offices, canteens, and restrooms. In 2021, Supplier F withdrew 6,203 m^3 of water from the borehole, with a reduction to 5,190 m^3 in 2022. This decrease was achieved through several water efficiency measures, including better monitoring and optimization of industrial processes. The municipal water supply is essential for the daily operations of the company's administrative and support functions. Despite an increase in the workforce, Supplier F managed to reduce the per capita municipal water consumption by 8% from 2021 to 2022 by implementing water-saving fixtures and promoting water conservation among employees.

Supplier F operates an Industrial Wastewater Treatment Plant (IWWTP) designed to treat the specific effluents produced by its industrial activities. The Industrial Wastewater Treatment Plant (IWWTP) has a maximum capacity of 80 m^3, with 60 m^3 allocated for the vibration process and 20 m^3 for the painting process. The treatment process includes effluent retention, oxidation, neutralization/coagulation, flocculation, sedimentation, sludge thickening, and filtration. Treated water is reused in production, and excess is safely discharged into the municipal collector managed by Águas da Região de Aveiro (ADRA).In 2022, Supplier F achieved an 11% decrease in the total volume of effluent discharged and a 37% reduction in effluent per piece produced. This improvement was due to enhanced water reuse practices and more efficient production processes.

Supplier F has implemented several measures to enhance water efficiency and reduce consumption:

- Daily Monitoring: Regular monitoring of water consumption helps identify inefficiencies and areas for improvement. This proactive approach enables Supplier F to address leaks and other issues promptly.

- Water-Saving Fixtures: The installation of taps with timers and flow reduction filters has significantly reduced water wastage in office and restroom facilities.

- Employee Awareness: Ongoing communication and awareness campaigns educate employees about the importance of water conservation. Events such as Water Day and World Ocean Day are marked to reinforce these messages.

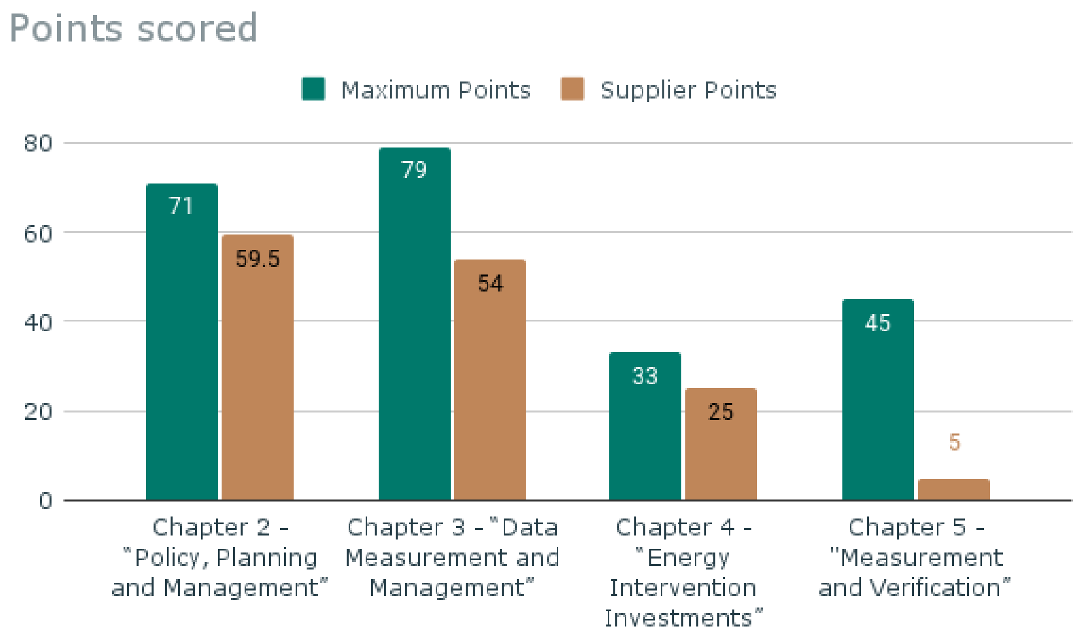

Figure 4.2: Supplier's F Parts Score

Supplier F's water management practices are critical for minimizing environmental impact and ensuring sustainable industrial operations. The company continues to explore innovative solutions to further enhance water efficiency and conservation.

4.4 Energy Efficiency Survey

In regards to the energy efficiency survey, supplier F is 3.1 points short of being considered mature. One can analyze this score by comparing it to the supplier's score in each part, as shown in figure 4.2.

In relation to Part 2, supplier F possesses a comprehensive management team dedicated to sustainability and energy efficiency. This enables the supplier to establish an energy efficiency policy with enduring goals aimed at diminishing energy and water usage. Supplier F currently generates less than half of its energy from its own solar panels. The remaining electricity consumed is sourced from a green contract, which effectively reduces its emissions. Furthermore, there are no intentions to substitute the current machinery with more effective models in the upcoming 3-5 years. In order to enhance its part score, Supplier F should strive to augment its renewable energy generation, integrate rainwater harvesting systems, and formulate a strategy for upgrading machinery to more efficient models.

Supplier F conducted an internal energy review to assess their consumption and identify the areas that require the most significant improvements in terms of data measurement and management. The supplier utilizes sub-meters to gather data at a granular level, both at the process level and specifically on the most crucial machines. These tracking devices allow for the establishment of a baseline model, from which KPIs can be derived. However, it does not monitor the daily energy usage for each individual item, it lacks a reference point for comparing the energy efficiency with similar products, and it does not possess a centralized air conditioning system. Improvements can be achieved by employing tools to track energy consumption for each individual product.

Supplier F selected the "Metal" process because it is directly involved in the manufacturing of bike components made of metal. In order to enhance their operational efficiency, Supplier F has the option to install a heat recovery system, establish Standard Operation Procedures (SOPs) for furnace operations, adopt water reuse strategies, and formulate guidelines for regulating seasonal temperatures in cooling systems.

Supplier F currently does not employ the practice of calculating monthly energy savings to recoup investments, nor do they measure energy savings in accordance with the IPMVP. To enhance performance, it is advisable to accurately calculate energy savings in order to accurately monitor investment returns. Additionally, it is recommended to adhere to the IPMVP protocol for energy savings verification to ensure consistent and standardized measurements.

Supplier F is categorized as "advancing" in terms of its level of energy efficiency maturity. The gaps identified in policy planning, data measurement, energy investments, and verification processes highlight specific areas that require improvement. By focusing on these specific areas, Supplier F has the potential to greatly enhance its sustainability and efficiency, thereby making significant progress towards attaining a high level of proficiency in energy management. Part 3 improvements are crucial for reaching the mature stage.

Chapter 5

Results and Improvements

This chapter shows the results of the energy efficiency survey, focusing on the anticipated activities outlined in the roadmap, as well as the outcomes of the water monitoring programs. The analysis we conduct centers around crucial indicators of energy usage, the integration of renewable energy sources, and the efficacy of existing steps to enhance efficiency. The results underscore the company's advancement towards sustainable practices and offer valuable insights into areas that can be further enhanced. The comprehensive results provide a basis for strategic planning and future initiatives aimed at ensuring long-term viability.

5.1 Suppliers Maturity Scores

The suppliers' scores at the beginning and end of the internship are displayed in Table 5.1. The priority list consists of 1 supplier (A), that achieved maturity, but it is still waiting to be validated by Decathlon's central team, 10 suppliers that are progressing (C, D, E, F, G, I, J, K, L, O) and 6 suppliers that are not yet mature (B, H, M, N, P, Q). Except for supplier H, whose survey was only confirmed during the internship, it is possible to observe a improvement in the scores of the other suppliers. The increase is the consequence of the suppliers investments and initiatives outlined in their specific roadmap. On the other hand, it is also a result of rectifying errors in prior iterations of the survey, particularly in Part 4. In this part, suppliers who did not had all the processes indicated in the survey were being penalized.

The list of suppliers can be categorized into three groups based on their performance: those that have reached maturity or are near it, with a score of over 40; those that are making progress, with a score between 29.5 and 33.5; and those that are not yet mature, with a score below 25. The similarity in scores arises from the varying stages at which each supplier is positioned.

Suppliers who are not mature lack internal analysis and knowledge regarding their energy and water usage. Furthermore, they lack awareness of the fact that energy efficiency measures not only lead to a decrease in CO_2 emissions, but also result in lower operating costs. These suppliers lack a dedicated staff to oversee the sustainability of their companies, resulting in the absence

Table 5.1: Suppliers Maturity Score

Supplier	Process	Initial Score	Current Score
A	BIKES	45.75	51.20
B	BIKES	14.45	16.10
C	HELMET	24.73	30.63
D	PLASTIC COMPOSITE	41.45	43.05
E	TEXTILE	45.95	47.75
F	BIKES	46.90	47.50
G	PACKAGING	43.80	44.40
H	FOOTWEAR	13.74	13.74
I	METAL	41.40	43.80
J	PLASTIC COMPOSITE	27.30	29.70
K	METAL	18.85	33.15
L	BIKES	39.26	41.93
M	FOOTWEAR	22.28	23.48
N	FOOTWEAR	14.15	17.30
O	BIKES	32.60	44.95
P	FOOTWEAR	20.20	21.40
Q	WOVEN	20.95	23.95

of energy and water reduction programs. Furthermore, they lack the necessary knowledge and financial resources to invest in measuring equipment and more efficient machinery.

Suppliers that have achieved the Progressing level but are still far from achieving the Mature level already demonstrate the knowledge and human resources that the preceding ones lack. This provider has already conducted an external energy audit. They are beginning to allocate resources towards acquiring measuring equipment to gain a deeper understanding of areas where they can reduce costs and make strategic investments. Following these measurements, the suppliers must allocate capital and resources to implement their reduction objectives, a perfect example is the supplier K that achieved the progressing level recently because of the investments made after their audit.

The suppliers that are approaching the mature stage already have complete management teams and strategies. They possess the energy consumption measuring instrument and energy already. To reach maturity, suppliers must integrate manufacturing information with energy consumption data to determine the energy intensity of their products, which is necessary to achieve a mature level of performance. Suppliers who have obtained instruments enabling them to monitor their real-time energy intensity are able to identify and promptly rectify leaks and power spikes, thus preventing the wastage of unneeded resources. These tools also enable the user to accurately assess the supplier's cost savings and return on investment for each investment.

Finally, the improvement of Supplier A to the "Mature" level has significantly contributed to achieving the KPI of having 25% of the priority list reach the mature stage. This milestone underscores the effectiveness of targeted action plans and continuous improvement efforts, demonstrating the potential for substantial advancements in decarbonization. By actively engaging and supporting suppliers, DPP has made considerable progress toward its sustainability goals, showcasing the positive impact of collaborative and well-coordinated initiatives.

It is also possible to examine that there is a clear association between the scores of our providers and their operational processes. The suppliers participating in the Bike and Packaging processes continually attain higher marks and have reached or are approaching a state of maturity in their energy efficiency measures. This can be attributable to their classification as energy-intensive consumers, which requires them to comply with SGCIE standards. Supplier B, an outlier in the Bike process, has a low score attributed to internal problems. However, the supplier is now dedicated to enhancing its energy efficiency in accordance with SGCIE criteria. This supplier, with more than a quarter of the total priority list weight, shows great potential to improve their score, and consequently improve the global DPP maturity score.

In contrast, suppliers in the Footwear industry, which is known for its smaller and more traditional operations, have lower rankings. These suppliers frequently oppose making investments in energy efficiency and water conservation because they have limited resources and are skeptical about the advantages. To improve their rankings, it is necessary to participate in specific efforts that showcase the long-term benefits of these expenditures.

Altough, the DPP KPI, is having 25% or more of the priority list weight in the "Mature" level, is possible to use other indicators to see the overall progress. The DPP score is computed by summing the products of each supplier's score and their respective weight in the overall CO_2 emissions, as indicated in table 3.1. The equation 5.1 illustrates the overall progress on the priority list and the reduction of total CO_2 tons, rather than focusing on single suppliers that may show significant success but have a relatively minor impact on the total reduction.

$$\text{DPP Score} = \sum_{i=1}^{17} \text{Weight} \times \text{Supplier Score} \tag{5.1}$$

Initially, the DPP maturity score was 31.62, which has now increased to 36.69. This growth exemplifies the diligent efforts that all suppliers are making towards achieving their aims. The increase in the DPP score reflects not just individual achievements but the collective progress of the entire supply chain. The improvement signifies enhanced collaboration, better adherence to energy efficiency protocols, and a more significant overall impact on reducing CO_2 emissions. This upward trend is a testament to the effectiveness of our strategic approach and the commitment of our suppliers to sustainable practices.

The focus on cumulative progress ensures that our efforts yield substantial environmental benefits, driving forward our mission to minimize the carbon footprint across the entire supply chain. The increased DPP score is a positive indicator of our trajectory towards achieving our long-term sustainability goals.

5.2 Suppliers Emissions

Despite the inability to disclose the CO_2 emissions for 2024, a comparison between 2022 and 2023 illustrates a notable decrease in total tons of CO_2 emissions from Decathlon's suppliers. Table 5.2 shows a 42.83% reduction from 2022 to 2023, partly due to a decrease in turnover from certain suppliers. However, the actual CO_2 emissions dropped by 24.5%, because of the contractual arrangements of green electricity, leading to zero emissions for suppliers relying solely on electric power. This significant reduction highlights the suppliers' commitment to SBTi targets and the impact of green electricity adoption.

The reduction in CO_2 emissions is a direct result of strategic measures taken by the suppliers, particularly in the context of their energy sources. The use of green electricity has played a pivotal role in achieving these results, demonstrating the effectiveness of sustainable energy practices. Supplier Q's transition to green electricity, resulting in zero emissions, is a prime example of this shift.

Although a similar drop from 2023 to 2024 is unlikely, it can be concluded that investments and pledges in energy efficiency are effective, indicating a continuing trend in emission reductions. The ongoing commitment to energy efficiency and the adherence to SBTi targets by the suppliers are expected to sustain the momentum of CO_2 reduction. This trend underscores the importance of sustainable practices and the positive impact of green energy adoption on reducing the overall carbon footprint.

By focusing on reducing CO_2 emissions through energy efficiency and green energy adoption, suppliers are making significant strides towards achieving their SBTi targets. This collective effort is reflected in the rising DPP score, showcasing the progress made and the potential for continued improvement in the future.

5.3 Water Monitoring

Monitoring water consumption is crucial for improving water efficiency, identifying leaks, and reducing costs. However, many of our suppliers lack advanced tools for tracking their water usage, relying solely on water bills to register their consumption. This rudimentary method of monitoring provides only a general overview of water use, limiting their ability to identify specific areas where improvements can be made. Without detailed data, it is challenging to implement targeted water-saving measures or detect leaks promptly, leading to missed opportunities for conservation and efficiency.

The absence of sophisticated water monitoring tools among our suppliers underscores the importance of raising awareness about the benefits of advanced water management practices. Educating suppliers on the value of installing water meters and automated monitoring systems can significantly enhance their ability to track and optimize water usage. By understanding precise

Table 5.2: Suppliers CO_2 Emissions for Decathlon

Supplier	Process	CO_2 Total Tons in 2022	CO_2 Total Tons in 2023
A	BIKES	1,998.0	770.0
B	BIKES	1,970.0	1,540.0
C	HELMET	989.0	960.0
D	PLASTIC COMPOSITE	607.0	110.0
E	TEXTILE	358.0	313.0
F	BIKES	286.0	16.0
G	PACKAGING	285.0	201.0
H	FOOTWEAR	179.0	19.0
I	METAL	138.0	88.0
J	PLASTIC COMPOSITE	137.0	124.0
K	METAL	129.0	21.0
L	BIKES	127.0	23.0
M	FOOTWEAR	114.0	50.0
N	FOOTWEAR	102.0	59.0
O	BIKES	83.0	17.0
P	FOOTWEAR	37.0	10.0
Q	WOVEN	20.0	0.0

water consumption patterns, suppliers can implement more effective conservation strategies, detect leaks early, and ultimately reduce water costs. Encouraging suppliers to adopt these practices is not only beneficial for them but also aligns with our broader sustainability goals.

Despite our efforts to engage and educate our suppliers on the importance of advanced water monitoring, only one supplier has successfully improved their monitoring practices. The remaining suppliers continue to rely on basic water bill data for tracking their consumption, which limits their ability to make significant efficiency gains. This lack of progress underscores the need for continued support and education in this area. The detailed results of our engagement with suppliers and their current water monitoring practices are summarized in the table 5.3 in contrast to table 3.3. It is apparent that suppliers M and N have shown improvement, resulting in an increase to 80% in the number of suppliers registering their data compared to the initial 60%. Additionally, among these suppliers, there has been an increase to 75% in the quality of data, compared to the previous 44,44%.

In contrast, supplier F has implemented a comprehensive water monitoring system that exemplifies best practices in the industry. We utilize a combination of mechanical, ultrasonic, and electromagnetic water meters strategically placed to monitor water usage across different areas and processes. This detailed approach allows us to track water consumption in real-time, identify inefficiencies, and make informed decisions to enhance water use. Our investment in smart water meters and IoT sensors enables remote monitoring and continuous data logging, providing a granular view of water usage that facilitates proactive management.

Supplier F's advanced water monitoring capabilities have led to significant improvements in water efficiency. For example, by regularly analyzing consumption data, we have been able to

Table 5.3: Water Monitoring Priority List Final Result

Supplier	Registering	Quality Data
A	Yes	Good
B	Yes	Bad
C	Yes	Good
D	No	
F	Yes	Good
G	Yes	Bad
H	No	
K	Yes	Good
L	Yes	Good
M	No	
O	Yes	Good
P	Yes	Good
Q	Yes	Good
R	Yes	Good
S	Yes	Bad

reduce borehole water usage by 43% per piece produced from 2021 to 2022. Our IWWTP allows for the effective reuse of treated water, further minimizing our environmental impact. These measures demonstrate the tangible benefits of sophisticated water monitoring systems and highlight the potential for similar improvements among our suppliers.

5.4 Maturity Level Improvements

Suppliers at the not mature level require foundational support to grasp the benefits of energy efficiency. These suppliers often lack awareness and understanding of the long-term benefits associated with energy efficiency and sustainability. Therefore, comprehensive awareness and education initiatives are imperative. These programs should aim to educate suppliers on the financial and operational benefits of energy efficiency, including cost savings, improved operational efficiencies, and the positive environmental impact.

Conducting detailed internal energy audits is a critical first step for not mature suppliers. These audits help identify inefficiencies and potential areas for improvement. They provide a baseline understanding of current energy consumption patterns and highlight opportunities for energy savings. Based on the findings from these audits, tailored energy reduction plans should be developed. These plans serve as a roadmap for suppliers to follow, outlining specific actions and timelines for achieving energy efficiency goals.

Furthermore, fostering a culture of commitment to energy efficiency is essential. Suppliers should be encouraged to make formal commitments towards achieving energy efficiency goals. This can be facilitated through signing pledges, setting targets, and regularly reporting progress. These commitments help ensure long-term adherence to energy efficiency practices and create a sense of accountability. Initiating awareness campaigns and educational workshops can significantly influence suppliers' understanding and commitment to energy efficiency. Such initiatives led to a marked improvement in supplier engagement and compliance with energy efficiency measures.

Suppliers that are progressing have laid the groundwork with general plans and commitments but require further investments to elevate their energy efficiency practices. These suppliers need to allocate capital towards upgrading their machinery and equipment to more energy-efficient models. Investing in advanced, energy-efficient machinery can yield substantial long-term cost savings and operational efficiencies. These upgrades not only reduce energy consumption but also enhance productivity and process reliability.

Installing sub-meters is another critical step for progressing suppliers. Sub-meters provide granular data on energy consumption at both the process and machine levels. This detailed insight enables suppliers to optimize their production processes, reducing energy waste and improving overall efficiency. Sub-metering allows for real-time monitoring of energy use, which can help identify areas of excessive consumption and opportunities for immediate corrective action. Utilizing the data from sub-meters, suppliers can implement targeted improvements and continuously monitor their impact.

Progressing suppliers should also focus on process optimization. This involves analyzing the data collected from sub-meters to identify inefficiencies and areas for improvement. By optimizing production processes, suppliers can reduce energy waste, lower operational costs, and enhance overall efficiency. Continuous monitoring and adjustment of processes ensure that energy efficiency measures are sustained over time.

Suppliers nearing maturity have implemented most of the necessary energy efficiency measures but need to fine-tune their operations to achieve optimal results. Real-time data integration is a pivotal improvement at this stage. Implementing systems that integrate real-time production and energy consumption data allows for the immediate detection of inefficiencies, such as leaks or surges. This integration provides a holistic view of energy use across the entire production process, enabling suppliers to identify and address issues promptly.

Establishing protocols for immediate correction of identified inefficiencies is essential. Suppliers should develop standardized procedures for responding to energy inefficiencies, ensuring that resources are not wasted and that energy consumption remains optimized. These protocols should include guidelines for regular maintenance, quick response to anomalies, and continuous monitoring.

Additionally, it is important for these suppliers to develop methods for calculating and understanding the Return on Investment (ROI) from their energy efficiency measures. By quantifying the savings and benefits, suppliers can reinforce the value of their efforts and make informed decisions about future investments. ROI analysis helps suppliers understand the financial impact of their energy efficiency initiatives and provides a basis for justifying further investments.

Nearing mature suppliers should also focus on integrating cross-live data of production and energy consumption. This advanced integration enables real-time monitoring and management of energy use, allowing suppliers to optimize their operations continuously. By understanding and calculating the savings achieved through energy efficiency measures, suppliers can demonstrate the tangible benefits of their initiatives and encourage further investment in sustainability practices.

Implementing these targeted improvements based on the maturity level of suppliers will significantly enhance the overall energy efficiency and sustainability of DPP suppliers. By focusing on foundational education and audits for not mature suppliers, investing in advanced equipment and sub-meters for progressing suppliers, and integrating real-time data and ROI analysis for near-mature suppliers, the company can ensure a comprehensive and effective approach to achieving its long-term sustainability goals. These improvements not only contribute to environmental stewardship but also drive economic benefits, reinforcing the importance of sustainable practices across the entire supply chain. Through continued collaboration and commitment to energy efficiency, Decathlon's suppliers can lead the way in sustainable industrial practices and achieve lasting environmental and operational excellence.

5.5 Needed Improvements by Sector

A detailed analysis of the necessary improvements identified across different sectors from the energy efficiency surveys and the creation of the roadmap. Each sector has unique challenges and opportunities, and addressing these areas is essential for its suppliers to further enhance their sustainability practices and achieve long-term energy efficiency goals. This specific processes and initiatives are concerned in the Part 4 of the maturity survey.

The footwear sector, comprising four suppliers, is characterized by traditional and small-scale factories that are not mature in their energy efficiency practices. These suppliers are responsible for the least amount of emissions, but their processes are inefficient due to the lack of automation.

One of the primary challenges in the footwear sector is the automation of machines, particularly through the implementation of Variable Frequency Drives (VFDs). VFDs can significantly reduce energy consumption by controlling the motor speed and torque according to the actual demand, thereby minimizing energy waste. Additionally, the temperature control in ovens used in the manufacturing process is another critical area needing improvement. Currently, the lack of precise temperature control leads to excessive energy use and inefficiency.

To overcome these challenges, it is essential to educate these suppliers about the benefits of energy efficiency and provide support for the adoption of automation technologies. The implementation of VFDs and advanced temperature control systems can lead to significant energy savings and operational efficiencies. To address this issue, implementing focused training initiatives and providing financial incentives can effectively promote the adoption of energy-efficient technologies in traditional industries.

The metal sector includes two progressing suppliers that have achieved good scores in their specific processes but lack the necessary measuring equipment to optimize energy use fully. These suppliers need to invest in advanced metering and monitoring equipment to gain detailed insights into their energy consumption patterns.

By installing sub-meters and real-time monitoring systems, metal suppliers can identify areas of excessive energy use and implement targeted improvements. This approach not only enhances energy efficiency but also improves overall process reliability and productivity. Continuous monitoring and data analysis are critical for sustaining energy efficiency gains and achieving long-term sustainability goals.

The dyeing sector, represented by a single supplier nearing maturity, complies with SGCIE regulations and is close to achieving full maturity in energy efficiency. However, there is a need to invest in a continuous washing box to enhance the efficiency of the dyeing process. A continuous washing box can significantly reduce water and energy consumption by optimizing the washing process and minimizing waste. This investment will help the supplier achieve higher efficiency levels and align with best practices in the dyeing industry.

The plastic sector consists of two suppliers nearing maturity. These suppliers are close to achieving full energy efficiency but still lack VFDs in their injection molding machines and automatic temperature control systems. Additionally, they need to implement systems for reusing cool-down water to minimize water waste.

Investing in VFDs and advanced temperature control systems can significantly enhance the efficiency of plastic manufacturing processes. Reusing cool-down water not only conserves water resources but also reduces energy consumption associated with heating and cooling processes. Technological innovation and resource optimization are crucial in driving energy efficiency in the plastic sector.

The textile sector, represented by a single supplier, has shown potential with a maximum score in Part 4 of the survey but lacks the necessary investment and commitment to achieve full maturity. This supplier needs to prioritize investments in energy-efficient technologies and commit to continuous improvement in energy management.

Providing financial incentives and technical support can encourage the textile supplier to invest in advanced energy-efficient machinery and process optimization. Establishing partnerships and collaborative initiatives to share best practices and resources, helping suppliers overcome financial and technical barriers to energy efficiency.

The "Other" category includes suppliers involved in components and assembly for bikes, packaging, and helmets. These suppliers have varied scores and specific needs based on their processes.

For instance, bike assembly and packaging suppliers may require investments in automation and advanced energy management systems to optimize their production lines. Helmet manufacturers may benefit from upgrading their molding and curing processes to more energy-efficient technologies.

Addressing the unique needs of each supplier in the "Other" category requires a tailored approach, combining education, financial incentives, and technical support. Sector-specific strategy that considers the distinct challenges and opportunities in each sub-sector, ensuring a comprehensive and effective approach to energy efficiency improvements.

Implementing these targeted improvements based on the specific needs of each sector will significantly enhance the overall energy efficiency and sustainability of the supply chain. By focusing on automation and temperature control in the footwear sector, advanced metering in the metal sector, process optimization in the dyeing sector, technological upgrades in the plastic sector, and tailored support for other sectors, the company can ensure a comprehensive and effective approach to achieving its long-term sustainability goals. These improvements not only contribute to environmental stewardship but also drive economic benefits, reinforcing the importance of sustainable practices across the entire supply chain.

5.6 Water Consumption Improvements

The limited water monitoring capabilities among the suppliers highlight the need for substantial improvements. Raising awareness about water conservation is essential for fostering a culture of sustainability within our supply chain. We are committed to engaging with our suppliers through training programs and awareness campaigns that emphasize the importance of efficient water use. By sharing best practices and success stories, such as supplier F's achievements, we aim to inspire and support our suppliers in adopting more advanced water monitoring techniques. This collaborative approach will not only enhance the sustainability of our supply chain but also contribute to the broader effort of responsible water management.

Encouraging suppliers to install advanced water meters and adopt automated monitoring systems is a critical step towards improvement. These tools can provide real-time data on water usage, allowing for precise tracking and early detection of leaks. By moving beyond the basic method of registering water use from bills, suppliers can gain a deeper understanding of their consumption patterns and identify specific areas where water-saving measures can be applied. Implementing such systems can lead to significant reductions in water usage and costs.

Additionally, regular data analysis and benchmarking can further drive improvements. Suppliers can log water consumption data regularly, maintaining historical records to identify trends and set realistic reduction targets. Benchmarking water usage against industry standards or historical data helps assess efficiency and guide decision-making processes. For instance, adopting practices like those used by supplier F, such as detailed consumption monitoring and the implementation of water-saving fixtures, can lead to substantial improvements in water efficiency.

Supplier F's commitment to continuous improvement in water management serves as a model for our suppliers. Our successes demonstrate the potential benefits of investing in advanced water monitoring and management practices. By working together and sharing knowledge, we can help our suppliers make significant strides in their water management efforts, ultimately contributing to a more sustainable and efficient supply chain.

Chapter 6

Conclusion

The purpose of this chapter is to offer a brief summary of the measures implemented to facilitate the decrease of carbon emissions in the production process of Decathlon's suppliers. Additionally, it seeks to emphasize any constraints and difficulties encountered during this undertaking. In addition, it suggests giving priority to energy efficiency programs and continuous water monitoring as crucial areas for future efforts, acknowledging their importance in attaining a sustainable future.

6.1 Overview and contributions

This dissertation, conducted as part of the Master's degree in Industrial Engineering and Management at the University of Porto, explores the critical area of decarbonization within industrial production, focusing on DPP. The primary goal was to enhance energy efficiency and monitor water consumption, thereby accelerating the decarbonization process among Decathlon's suppliers.

The research methodology, involving updated surveys, on-site visits, and detailed action plans, proved effective in assessing and improving suppliers' compliance with SBTi. The approach prioritized suppliers nearing maturity to meet the 2024 KPI of having 25% of the priority list weight reach the "Mature" level, that was met. This targeted strategy not only facilitated immediate improvements but also set a foundation for long-term sustainability.

Key findings from the dissertation highlight the importance of tailored, sector-specific interventions. For instance, automation and temperature control were crucial in the footwear sector, advanced metering in the metal sector, and process optimization in the dyeing sector. These improvements significantly enhanced energy efficiency and sustainability, contributing to both environmental stewardship and economic benefits.

The project underscored the necessity of continuous monitoring and innovation. The collaboration between Decathlon and its suppliers was pivotal, demonstrating that shared knowledge and efforts could lead to substantial progress in sustainability goals. Regular data analysis and benchmarking emerged as essential practices, driving continuous improvements and ensuring compliance with environmental standards.

One of the significant challenges identified was the varying levels of maturity among suppliers. Addressing this required customized action plans and consistent support to ensure all suppliers could progress towards higher efficiency levels. Additionally, the project highlighted the critical role of advanced technologies, such as smart sensors for water monitoring, which can provide real-time data and enable precise tracking of resource usage.

The dissertation concludes that systematic and well-coordinated efforts can significantly advance decarbonization in industrial production. The success of the project at DPP sets a precedent for other companies aiming to achieve similar sustainability goals. Future research could explore the integration of new technologies and more comprehensive data analytics to further enhance energy efficiency and decarbonization efforts.

Through this study, Decathlon's commitment to sustainability has been clearly demonstrated. The findings contribute valuable insights into the practical implementation of decarbonization strategies, aligning industrial practices with global environmental targets. This work not only advances academic understanding but also offers a practical framework for industries aiming to achieve significant reductions in their carbon footprints.

6.2 Future work

Building on the findings and successes of this dissertation, several avenues for future work can further enhance the decarbonization efforts within DPP and beyond. The following steps are recommended to ensure continuous improvement, increase supplier awareness, and encourage smaller companies to participate actively in decarbonization initiatives.

To maintain momentum in decarbonization efforts, it is crucial to implement a continuous improvement framework. This involves regular reassessment of energy efficiency and water consumption strategies to adapt to new technologies and evolving industry standards. Establishing a cycle of periodic reviews and updates ensures that improvements are sustained and built upon, fostering a culture of ongoing environmental stewardship. Key actions include conducting annual reviews of energy and water usage data to identify areas for further improvement, staying abreast of advancements in green technologies and integrating them into production processes where feasible, and regularly benchmarking performance against industry leaders to incorporate best practices and drive further efficiency gains.

Increasing supplier awareness of the necessity and advantages of decarbonization is vital for achieving widespread impact. This can be achieved through targeted education and communication strategies that highlight both the environmental and economic benefits of energy efficiency and water monitoring. Workshops and training sessions can be organized to educate suppliers about decarbonization benefits and methods, sharing success stories and case studies of suppliers who have successfully implemented energy efficiency measures, and providing suppliers with comprehensive resource materials, including guidelines, toolkits, and checklists for implementing decarbonization strategies.

Smaller companies often face resource constraints that can hinder their participation in decarbonization efforts. Encouraging these companies to conduct audits and engage in energy efficiency initiatives is essential for a comprehensive approach to reducing emissions. This can be achieved by offering subsidized or free energy audits for smaller companies to assess their energy usage and identify improvement opportunities, developing partnership programs where larger companies mentor and support smaller suppliers in conducting audits and implementing recommendations, and simplifying the audit process to make it more accessible and less resource-intensive for smaller companies.

To avoid misunderstandings and ensure accurate data collection, conducting surveys in person can be highly effective. This approach allows for real-time clarification of questions and ensures that responses accurately reflect the supplier's situation. On-site visits should be scheduled to administer surveys and gather data in person, using interactive sessions during visits to explain survey questions and ensure suppliers understand the importance and implications of their responses. Immediate feedback and recommendations should be provided during the visit to help suppliers understand areas for improvement.

Future work in decarbonization at DPP should focus on continuous improvement, increasing supplier awareness, encouraging smaller companies to engage in audits, and administering surveys in person. These steps will help ensure that the momentum gained through this dissertation is sustained and that Decathlon continues to lead by example in achieving environmental sustainability. By fostering a culture of ongoing improvement and collaboration, DPP can significantly contribute to global efforts to reduce carbon emissions and promote sustainable industrial practices.

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Appendix A

Reflection on Sustainable Development Goals

A.1 Climate Action (SDG 13)

The thesis primarily focuses on strategies to reduce carbon emissions within industrial production at DPP. This aligns closely with Sustainable Development Goal (SDG) 13, which calls for urgent action to combat climate change and its impacts. By developing strategies for energy efficiency and water monitoring, the thesis contributes directly to mitigating climate change and reducing the carbon footprint of industrial activities.

A.2 Affordable and Clean Energy (SDG 7)

Improving energy efficiency and transitioning to renewable energy sources are crucial aspects of the thesis. These efforts are aligned with SDG 7, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all. The focus on enhancing energy efficiency among suppliers supports this goal by promoting cleaner production methods and reducing dependency on fossil fuels.

A.3 Responsible Consumption and Production (SDG 12)

The thesis's emphasis on monitoring and improving energy and water use in production processes supports SDG 12, which aims to ensure sustainable consumption and production patterns. By implementing comprehensive action plans and fostering supplier compliance with sustainable practices, the thesis promotes more responsible resource management and operational practices.

A.4 Industry, Innovation, and Infrastructure (SDG 9)

By prioritizing innovation in energy efficiency and water use, the thesis supports SDG 9, which focuses on building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. The systematic improvements and collaborations between DPP and its suppliers underscore the importance of innovation in achieving sustainability goals.

A.5 Reflection and Insights

The thesis's comprehensive approach to decarbonization through practical implementation strategies not only addresses specific environmental goals but also highlights the broader economic and social benefits of sustainable practices. For instance, the economic advantages derived from improved energy efficiency and reduced water consumption demonstrate the potential for achieving both environmental and operational excellence. This dual benefit is a testament to the feasibility and desirability of integrating sustainability into core business strategies.

Moreover, the collaborative framework between DPP and its suppliers mirrors the SDGs' emphasis on partnerships (SDG 17), showcasing how cooperation and shared goals can drive significant progress towards sustainability. The focus on continuous monitoring, innovation, and adaptation of strategies ensures that the efforts remain relevant and effective in the long term, which is essential for achieving the ambitious targets set by the SDGs.