Decision Support System for Minimizing Food Waste in Agri-food Supply Chains

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To my parents and sister
For the unconditional love, guidance and support
I am very glad for the life you provided me with

Declaração

Declaro que o presente documento é um trabalho original da minha autoria e que cumpre todos os requisitos do Código de Conduta e Boas Práticas da Universidade de Lisboa.

Declaration

I declare that this document is an original work of my own authorship and that it fulfills all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

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Abstract

About one third of all food produced for human consumption worldwide is lost or wasted throughout the supply chain before it is delivered to the final customer. This situation compromises the creation of a more sustainable agri-food sector. In this context, this work was developed with the goal of helping companies and supply chains be more sustainable and efficient. With this purpose, this work breaks down into four primary axes: (i) the development of a general sustainable agri-food supply chain network (ii) the creation of a measurement system (iii) the development of a tool to measure the performance of the company in terms of the three pillars of sustainability (iv) the validation of the tool. Through a literature review, a detailed analysis of a general sustainable agri-food supply chain will be conducted and a measurement system proposed. This will lead to a tool with the goal of helping companies and supply chains improve their performance considering the three pillars of sustainability. Finally, this tool is applied to the Greenyard company and so its current performance is evaluated in terms of sustainability, as well as its progression. In the end some improvements to the measurement system are given, as well as, some actions to improve the company's KPIs. This way the scientific community will have an innovative way to measure in quantitative terms the sustainability of an agri-food supply chain.

Keywords: Agri-food Supply Chain; Sustainability; Decision Tool; Performance Measurement System

Resumo

Cerca de um terço de todos os alimentos produzidos para consumo humano em todo o mundo são perdidos ou desperdiçados em toda a cadeia de abastecimento antes de serem entregues ao consumidor final. Esta situação põe em causa a criação de um setor agroalimentar mais sustentável. Neste contexto, este projeto foi desenvolvido em resposta à ameaça iminente que o desperdício e a perda de alimentos representam para os três pilares da sustentabilidade.

Este trabalho visa ajudar empresas e cadeias de abastecimento a serem mais sustentáveis e eficientes. Para atingir este objetivo, esta dissertação divide-se em quatro eixos principais: (i) o desenvolvimento de uma rede geral da cadeia de abastecimento agroalimentar sustentável (ii) a criação de um sistema de medição dessa cadeia (iii) o desenvolvimento de uma ferramenta para medir o desempenho da empresa ao nível dos três pilares da sustentabilidade. (iv) validar a ferramenta.

Através de uma revisão da literatura, foi realizada uma análise detalhada de uma cadeia de abastecimento agroalimentar sustentável comum e foi proposto um sistema de medição. Neste seguimento, foi criada uma ferramenta em Microsoft Excel, a Eco-tool, com o objetivo de auxiliar empresas e cadeias de abastecimento a melhorar o seu desempenho tendo em consideração os três pilares da sustentabilidade. Por fim, esta ferramenta é aplicada à empresa Greenyard e assim avalia-se o desempenho atual desta empresa em termos sustentáveis, bem como a sua evolução ao longo do tempo. No final são dadas algumas ações para melhorar os KPIs da empresa. Desta forma, a comunidade cintifica passará a ter uma ferramenta que mede a sustentabilidade das cadeias agro-alimentares de uma forma quantitativa.

Palavras Chave: Cadeia de abastecimento agroalimentar; Sustentabilidade; Ferramenta de Apoio à Decisão; Sistema de medição do desempenho

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Abbreviations

AFSC	Agri-Food Supply Chain
CE	circular economy
FLW	food loss and waste
GHG	Greenhouse Gas
KPIs	Key Performance Indicators
LCA	Life Cycle Assessmen
NLP	Natural Language Processing
PMS	Performance Measurement System
SAFSC	Sustainable Agri-Food Supply Chain
SCM	Supply Chain Management
SCV	Supply Chain Visibility
SDGs	Sustainable Development Goals
SSC	Sustainable Supply Chain
SSCM	Sustainable Supply Chain Management
VSM	Value stream mapping

Chapter 1

Introduction

1.1 Problem Background and Motivation

On September 25th 2015, according to the Food and Agriculture Organization of the United Nations (FAO, 2015), all 193 Member States of the United Nations agreed on adopting 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development (see Figure 1.1). These are global objectives that should be used to guide the actions during the next 15 years (2016-2030). There are hundreds of millions of people suffering from hunger and, at the same time, about one third of all food produced and processed for human consumption worldwide is lost or wasted throughout the supply chain before it is delivered to the customer (HLPE, 2014).

This amount of food, wasted or lost, can be translated in a measurable quantity of approximately 1.3 billion tons of food every year, and the high-income countries are responsible for half of that amount (FAO et al., 2017). This quantity of food occupies 1.4 billion hectares of land, which is almost 30 per cent of the total agricultural land area (BIO-Intelligence Service and FAO, 2013). When it comes to the energy consumption, the agri-food sector is responsible for 30 per cent of the world's total energy consumption, and those losses represent 38% of this energy (FAO et al., 2017). Even though there is some production in the developed countries, there is also a lot that is done on developing countries, where it is more difficult to find proper resources. These countries' population typically has low food availability (low food consumption per capita) and high population growth, which compromises food security, especially where semi-arid agriculture is predominant and import capacity is limited. Therefore, the production of food is not always sustainable and so the twelfth goal of the United Nation (UN) - Ensure sustainable consumption and production patterns - is compromised. (BIO-Intelligence Service and FAO, 2013).

According to FAO (2017), the food produced and not eaten have an estimated carbon footprint of CO_2 equivalent of 3.3 Gtonnes without considering the Greenhouse Gas (GHG) emissions from land use. This waste can be also translated in a blue water footprint, which is the surface and groundwater used for its production, of around 250 km^3. All these emissions and wasted resources will have an impact on the environment preventing the climate change combat, which compromises the thirteenth UN goal - Take urgent action to combat climate change and its impacts. There is also an impact on the biodiversity that although is very different to measure, should also be considered.

Additionally, the inefficiency of current food systems can be translated into economic losses, not only for farmers, but also for other stakeholders involved in the food supply chain. This situation also leads to an increment of the selling prices, which makes the food even more unavailable to vulnerable groups, compromising the food security and leading to more hunger worldwide. This condition makes the second UN goal more unachievable - End hunger, achieve food security and improved nutrition and promote sustainable agriculture (FAO et al., 2017).

Thus, if it was possible to reduce food losses and waste, the supply of available food would increase, which would improve the food security. Moreover, this volume of food waste and loss, makes the transformation of agri-food supply chain into a sustainable food system a challenge. Reconfiguring the food supply chains and introducing sustainable technologies would allow to recycle resources more effectively and require less transportation and storage. This development would improve the food sector, while reducing GHG emissions (FAO et al., 2017). However, transforming the supply chain into a sustainable one needs to be done carefully in order to make sure the changes that are being made are reducing the amount of food loss and waste. To do so, one of the most important tasks is identify the hotspots where the loss is occurring and find a way to measure them considering the three pillars of sustainability.

Figure 1.1: Sustainable Development Goals
(source: FAO Regional Office for Asia and the Pacific)

1.2 Objectives and Methodology

This master's dissertation aims to create a general tool to monitor and measure any company and agri-food supply chain's performance in terms of the three pillars of sustainability (economy, society and environment). This tool will also help improving their performance since it analyses the impact of the decisions made by ensuring that these changes are creating more sustainable companies and supply chains. In Figure 1.2 is presented the structure of the dissertation.

To achieve the aimed result, the following methodological steps will be developed:

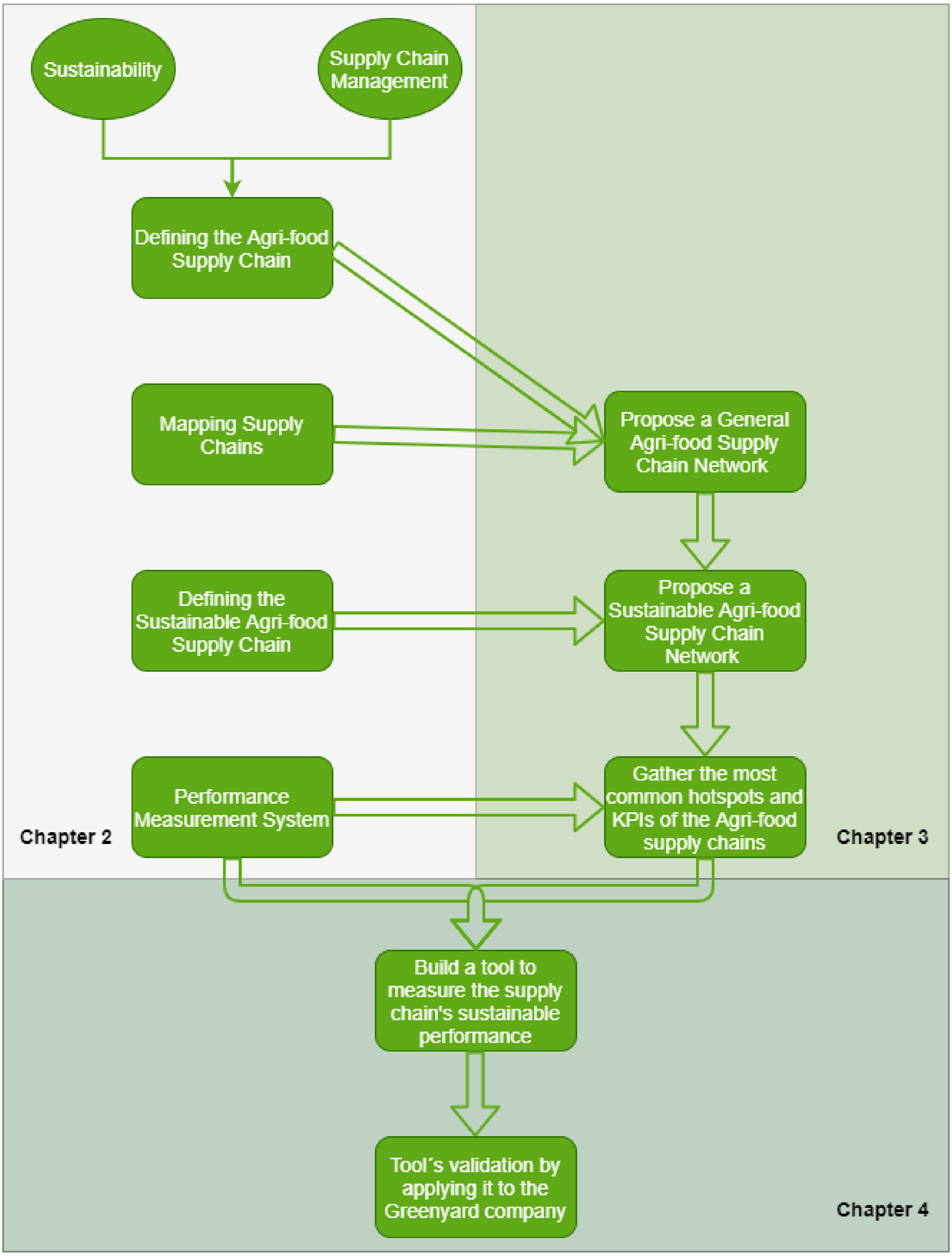


Figure 1.2: Thesis Structure

1. Define the main concepts related with sustainability, supply chain management and agri-food supply chain.
2. Explain the purpose, importance and how to create a supply chain map.

3. Create a general agri-food supply chain network considering the information gathered in the first two items.
    - Describe the entities and flows that compose this type of supply chain.
    - Explain the key terms related with the agri-food industry to avoid misunderstandings.
4. Describe what is a sustainable agri-food supply chain taking into consideration the definitions of the first item.
5. Transform the supply chain proposed in item 3 into a sustainable agri-food supply chain network.
    - Explain the importance of this transformation in the three pillars of sustainability.
    - Define the changes that are going to be made and the impact that is expected to have on the supply chain performance.
6. Describe what a performance measurement system is and its relevance to monitor and measure the company or supply chain's performance.
7. Gather the most common hotspots of each entity of the supply chain, considering the network proposed in the item 5 and the information of the item 6.
    - Determine KPIs to measure each hotspot and its reference value, when available.
    - Suggest some improvement actions to help companies reduce and eliminate those hotspots.
8. Build a tool to measure any company and supply chain sustainable performance, considering everything presented previously. However, giving a special attention to the most common hotspots and the respective KPIs and their reference values, as well as, the sustainable agri-food supply chain network.
    - Define the aim and assumptions of the tool.
    - Describe the tool's structure.
9. Apply the tool to the Greenyard company to measure its hotspots and see how they are progressing.
    - Describe the Greenyard company, the different products that it is responsible for and its structure.
    - Interpret the results of the tool and give some possible improvement actions to the Greenyard company.
    - This will give an idea of the capabilities of the tool and the steps that the user needs to go through in order to apply it.
    - Gather the tool's limitations detected while using it.

1.3 Document Structure

The project will be divided into five chapters: Introduction, Literature Review, Mapping Agri-Food Supply Chains, The Eco-Tool Foundations and Conclusions and Future Work Suggestions.

The Introduction is the current chapter (Chapter 1) and starts with the work contextualization, where the importance of the chosen theme is explained, followed by the definition of objectives and finally the document structure. It starts by explaining what the Sustainable Development Goals are, and how reducing the food waste and loss can help achieving them.

The Literature review, Chapter 2, will focus on sustainability, agri-food sector and its supply chains, in particular the sustainable ones and how to adjust and measure them. In the end, it will be discussed how supply chain mapping can help in making these tasks possible. In this context, this chapter will be divided into six sections:

- **Section 2.1** - Sustainability
- **Section 2.2** - Sustainable Supply Chain Management
- **Section 2.3** - Sustainable Agri-food Supply Chain
- **Section 2.4** - Supply Chain Mapping
- **Section 2.5** - Developed Cases Regarding Mapping Agri-Food Supply Chain
- **Section 2.6** - Importance of Measuring a Food supply Chain Network

Mapping Agri-Food Supply Chains, Chapter 3, consists in explaining a general sustainable agri-food supply chain network and presenting important concepts related with food loss and waste. Then, it is studied how to transform this network into a sustainable one. In the end, a more focused literature review is done, in order to gather the most common hotspots of the agri-food supply chain, and possible KPIs to measure them.

The Eco-Tool Foundation, Chapter 4, is where the tool is created and presented. The aim of this tool is to help companies to achieve a better performance in terms of the three pillars of sustainability. Also, in this chapter a validation of the tool, concerning the Greenyard company, is performed.

Finally, the **Conclusion and Future work**, Chapter 5, will be developed as a summary of the project's work, where the most important findings will be highlighted and, in the end, some limitations of this work and possible future developments will be suggested.

Chapter 2

Literature Review

The goal of this chapter is to review the existing literature to provide basis of knowledge and possible approaches to the problem presented in the previous chapter. The aim is to analyze the Agri-food supply chains and identify the challenges posed to make them sustainable and how to measure their sustainability. Having this target into account, the structure of this chapter will be organized in 6 sections.

In Section 2.1. the key concepts associated with sustainability are defined and afterwards in Section 2.2 applied to the supply chain concept in order to understand how to transform a supply chain into a sustainable one. In Section 2.3 the agri-food supply chain is described with a focus on the sustainable one and an analysis is made on how circle economy and life cycle assessment can help make these supply chains more sustainable. For both strategies, is presented successful case studies applied to the agri-food sector. In Section 2.4 the possibility of mapping the supply chain in order to better measure and manage it is addressed. Then, in Section 2.5 methodologies that were applied in other case studies to map agri-food supply chains will be described. In Section 2.6 the performance measurement system and its importance is discussed, as well as the need to use the right key performance indicators.

The data for this chapter was obtained through literature review including books, articles, papers and webpages. They were found using search engines like Google Scholar and specific data sources, specially ScienceDirect and ResearchGate. The key words applied were, among others, ”Sustainability”; ”Supply Chain Management”; ”Agri-food”; ”circular economy”; ”key performance indicators”; ”supply chain management”; ”Life Cycle Assessment”; ”case studies”; ”Mapping”; ”Visibility”. All papers considered were in English or in Portuguese.

2.1 Sustainability

In the ”Report of the World Commission on Environment and Development: Our Common Future” (Imperatives, 1987) sustainability is defined as the ability to meet the needs of the current generation without compromising the ability of the future generations to do the same. Later in 1994, Elkington (1994) created the *Triple Bottom Line Concept*, a framework that proposed three dimensions to define sustainability: environmental, social and economic. This framework is also known as the 3Ps: planet, people and profit. This approach was the first one that considered environmental and social measures to define sustainability. However, the social and environmental dimensions can be very hard to measure.

The economic pillar includes the growth of the organization, which contributes to the growth of the economy. Therefore, it focuses on the economic value provided by one organization to the surrounding system in order to prosper it and to promote its capability to support future generations (Arowoshegbe and Emmanuel, 2016). The issues associated with this pillar are not only the ones conventionally reported in the company's annual financial report, but also matters like the ratio of investments in human capital, research and development, wages and benefits paid and community development initiatives (Goel, 2010).

The social pillar is about conducting beneficial and fair business practices to the labor, human capital, and the community in order to provide value to the society (Arowoshegbe and Emmanuel, 2016). These practices may include ratio of wages to cost of living and providing health care coverage and safety. Moreover, the social performance addresses interactions between an organization and its community (Goel, 2010).

The environmental pillar is related to encouraging practices that do not compromise the environmental resources for future generations. It covers the efficient use of energy resources, reducing greenhouse gas emissions, and minimizing the ecological footprint. Environmental performance includes also factors such as, the amount of energy consumed and its origin, resource and material usage, emissions, effluents and waste management, land use and management of habitats (Arowoshegbe and Emmanuel, 2016).

Carter and Rogers (2008) proposed other aspects of sustainability that were not explicitly included in the definitions of the triple bottom line and are influencing the supply chain. These aspects are the supporting facets of the triple bottom line and consist in risk management, transparency, strategy, and culture. According to these authors supply chain risk management is the capacity that a firm has to understand and manage its supply chain economic, environmental, and social risks. Transparency comprises reporting to stakeholders, as well as continuously engage with them and using their feedback and input to both secure buy-in and improve supply chain processes. Strategy and culture defend that to become sustainable enterprises, organizations need more than simply overlay sustainability initiatives over corporate strategies, they also have to incorporate those initiatives in their company cultures and mindsets. In this context, is then important to understand how to apply this concept to a supply chain.

2.2 Sustainable Supply Chain Management

To understand what a sustainable supply chain management is, first supply chain and supply chain management will be described. Then, sustainable supply chain and sustainable supply chain management will be defined by adding the information presented on the previous section with these two definitions.

Handfield and Nichols (2000) characterized supply chain as all activities associated with the flow and transformation of goods from the raw materials until the end user, as well as the associated value and information flow. Later, in 2001, Supply Chain Management (SCM) was defined as a systematic coordination of the strategic business functions and the tactics within a company or the supply chain.

The goal of the supply chain is to improve the long-term performance of the individual companies and the supply chain as a whole (Mentzer et al., 2001).

Considering sustainability, as well as what is understood as SCM, it is now important to characterize sustainable supply chain management (SSCM). Over the years many researchers have given different definitions. However, for this study will be only considered the most cited ones. According to Seuring and Müller (2008), SSCM is not only the management of the material, information and capital flows, but also the coordination between entities along the supply chain, while taking into account the three dimensions of sustainable development. The environmental and social criteria need to be fulfilled by the members within the supply chain in order to guarantee competitiveness by meeting customer needs and related economic criteria while being sustainable.

Carter and Rogers (2008) also describe SSCM as the strategic, transparent integration and accomplishments of the organization’s sustainable development goals in a systematic coordination of the key inter-organizational business processes in order to improve the long term environmental, social and economic performance of the company and its supply chain. This definition takes into account the triple bottom line, as well as the four supporting facets of sustainability. The most recent one describes sustainable supply chain (SSC) as a complex network of systems that includes diverse entities that manage the products from suppliers to customers and their associated returns, accounting for social, environmental and economic impacts. The study of such systems is becoming more relevant to the companies due to growing society’s awareness towards environmental and social problems (Barbosa-Póvoa, 2014, Barbosa-Póvoa et al., 2018).

Today, some companies are starting to transform their supply chain into a sustainable one. Although, they set proper expectations for supply chain sustainability, most fail to implement tangible measures that make sure there is a compliance to such actions. This situation happens because it is challenging for companies to understand the true meaning of SSC within the organizations and how this should be managed among the different entities involved. Additionally, with the increasing interest in responsible SCM, the numbers of initiatives have risen in every sector generating a range of methods and standards, leaving companies with the discouraging task of identifying the most appropriate practices to use. That is why, a clear understanding of the meaning of SSC and of what is important at the corporate level is crucial. Moreover, the huge size and complexity of global SCs means that when companies begin their efforts towards sustainability need tools to support their decision-making process from the strategic to the operational levels, where the presence of uncertainty and risk is an increasing reality that must be dealt with (Barbosa-Póvoa et al., 2018). After defining what a general supply chain is, it is time to go deeper into the project’s theme and to study an agri-food supply chain with a focus on the sustainable agri-food supply chain.

2.3 Sustainable agri-food supply chain

The agri-food supply chain (AFSC) accommodates a wide range of entities from ”farm-to-fork”, which are farmers, suppliers, cooperatives, pack-houses, transporters, exporters, importers, wholesalers, retailers and finally customers. The structure of the agri-food industry can be very complex, and for some products it is slightly extended with many entities, which results in many interactions (Doukidis et al., 2007). The raw materials are sourced by the primary producers and sold to the suppliers. The processors or manufacturers purchase the inputs from the suppliers and process them to produce the packaged food items. The items are then transferred to the wholesaler and then shipped to the retailer where they are, in the end, purchased by the consumers. There are some differences when considering some food items, for instance, fresh produce may not require processing (Malik et al., 2018). These operational echelons are helped by logistical, financial and technical services and supported by three flow types: material flow, financial flows and information flows (K.Tsolakisa et al., 2014). The ultimate goal of the AFSC is to provide the right products (quantity and quality), in the right time and at a competitive cost in order to earn money with it (Jaffee et al., 2010). In Chapter 3 a detailed description of each entity role and an explanation of each flow will be given.

After understanding the importance of sustainability and defining AFSC management, it is important to describe how to achieve a sustainable agri-food supply chain (SAFSC). According to a recent study produced by the EAT-Lancet Commission and published in *Nature* (EAT Commission, 2019), one single solution to create a sustainable agri-food system is not sufficient to avoid crossing planetary boundaries. However, when various solutions are implemented together, their research shows that it may be possible to feed the growing population in a sustainable way. In order to be effective, the change needs to be at the system level. Thus, a food system based on the principles of a circular economy (CE) is one that is healthy for people and natural systems (Ellen Macarthur Foundation, 2019).

A proper environmental assessment tool is necessary to evaluate to what extent food production affects the environment. Different types of assessment tools have been developed to establish environmental indicators, which can be used to control the environmental impact of livestock production systems or agri-food. The environmental assessment tools can be area based or product based. The area-based indicators are usually used for farm emissions of nutrients, like nitrate that influences the local environment. On the other hand, when considering the greenhouse gas emissions from the agri-food, the product-based indicators are useful for evaluating the impact of food productions on the global environment, such as climate change. In addition, product-based indicators also assess the emissions from the farm related to the production of inputs, for instance, artificial fertilizer and outputs like slurry exported to other farms. In that way it is easier to avoid shifting environmental problems from one place to another, which reduces its cumulative environmental impacts. Product-based evaluation is called, life cycle assessment (Mogensen et al., 2009).

For these reasons, in order to study methodologies to make AFSCs more sustainable, it is going to be presented two different approaches that can be combined or used separately: the circular economy and the life cycle assessment approaches. These were the chosen methodologies since they appeared in the articles as the most adequate ones to successfully transform an AFSC into a sustainable one. These methodologies had already been explained in detail and had led to a great impact in the agri-food industry.

2.3.1 Circular Economy

There is no common definition of circular economy, but it is an organizational principle that is based on the current economic model, that defends that the resources are extracted, manufactured, consumed and wasted. However, in this CE model, the waste will reenter the system. Moreover, this model values the resource efficiency during every stage of the value chain (Benetto et al., 2018). The European Commission defines CE as the process where the value of products, materials and resources is preserved in the economy for as much time as possible and the creation of waste is minimized (European Commission, 2015). This way, CE is an approach to reduce the need of primary resources based on the 4Rs principle: reducing, reusing, recycling and recovering on a micro (enterprise) and meso (industrial park) and macro (regional) level (Kirchherr et al., 2017).

CE applied to agriculture is centered on the production of agri-food commodities using the least amount of external inputs possible, closing nutrient loops and reducing negative discharges to the environment (in the form of wastes and emissions). Analyzing the entire agri-food system using the CE perspective can disclose opportunities at all stages, from primary production using precision agriculture techniques, to the recycling and utilization of agricultural wastes (Ward et al., 2016).

Environmental benefits can be associated with business profit, as long as firms consider the 4Rs to value resources starting from the raw materials until the end of the product life cycle. The recovery process may generate a new product line for a segment of existing customers, as well as new customers creating additional profitability and achieving environmental sustainability (Pohlmann et al., 2020). Simultaneously, the usage of resources in a sustainable way will save energy and will avoid the irreversible damages in climate, biodiversity, air, soil and water pollution. However, implementing a CE system besides economic and environmental impacts, also has social impacts. For instance, this system should avoid resources scarcity, and so protecting against the prices volatility. It will also create new business opportunities and local jobs at all levels of qualification, which allows opportunities for social integration and cohesion (European Commission, 2015).

2.3.2 Circular Economy Applied to Agri-food

It is very important to understand where CE has been used and to what end. There were already some authors that have applied the concept of CE in the agri-food industry. Del Borghi et al. (2020) discussed on his paper how the concept of CE can be applied from a theoretical framework into an integrated approach and policy. Thus, the paper refers to using CE principles and tools based on a life cycle assessment to understand the interconnections along the entire supply chains in order to reduce the water, energy and food consumption. Toop et al. (2017) developed an integral analysis of the agri-food value chain, starting from the livestock and crop production until the food processing and retail sector. The goal was to provide mechanisms to achieve an increase in the recycling and valorization of agri-food waste by creating new sustainable value chains, for instance by maximising the use of by-products and co-products.

Genovese et al. (2017) addressed how can sustainable supply chain management be enhanced by aligning it with the CE concept and comparing the environmental implications of circular production systems with traditional linear production paradigm in terms of carbon emissions, resource use and waste recovered. The authors also consider the potential market dynamics, policy and societal implications caused by the implementation of circular production systems and the challenges they pose. This analysis was based on two case studies one about the food industry (specifically, the waste cooking oil supply chain) and the other about the chemical industry.

D'Amato et al. (2019) analyzed corporate reports to explore how the concepts of CE, green economy, and bioeconomy vary according to the sector and geographic provenience of the companies in land-use intensive sectors (forest, food, beverages, mining, and energy). The main theoretical framing of this study is the dynamic loop linking public and corporate discussion on sustainability, as well as the isomorphic influence among companies.

Recently, Pohlmann et al. (2020) developed a study that aims to discuss the role of the focal company in sustainable development goals in a Brazilian food poultry supply chain. Among various possibilities, CE is defined as a possible approach to achieve sustainable orientation.

Also, in companies this has been a concern, to understand how the CE approach could be applied in a company context, it is going to be presented the case of the **Woolworths Supermarkets**. They are the biggest chain of grocery store in Australia (995 stores) and purchase 96 per cent of fruit and vegetables and 100 per cent of the meat from Australian farmers. In order to solve the waste problem in June 2019 the company announced that all its supermarkets have implemented an active flow waste diversion program. This program involves redirecting food that is still fit to human consumption into hunger relief charity partners and the rest is donated to stock feed to farmers and sending the waste for commercial organic composting. Woolworths also partnered with Triple Breweries to create a CE beer (Loafer), that was a limited-edition pale ale produced with left over bread. This new supply chain allowed 55,000 tonnes of food being diverted from landfill, 10 million meals have been delivered across the country and 33,000 tonnes of surplus food that were no longer fit for human consumption but suitable for livestock feed or composting were given to farmers and community groups (KPMG, 2019). After analyzing the CE as a strategy to create a SAFSC, it is time to describe the other approach: life cycle assessment.

2.3.3 Life Cycle Assessment

Life cycle assessment (LCA) is a "cradle-to-grave" approach to analyze all stages of a product's life. "Cradle-to-grave" begins with the raw materials acquisition through production, use and disposal. LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle (IS0 14040, 1997). Hence, it enables a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection (SAIC and Curran, 2006). In order to do so, LCA considers an inventory of relevant energy and material inputs and environmental releases with the goal of evaluating the potential environmental impacts associated with the identified inputs and releases (IS0 14040, 1997). LCA processes have been standardized (e.g., ISO 14040) and follow the main steps of (see Figure 2.1):

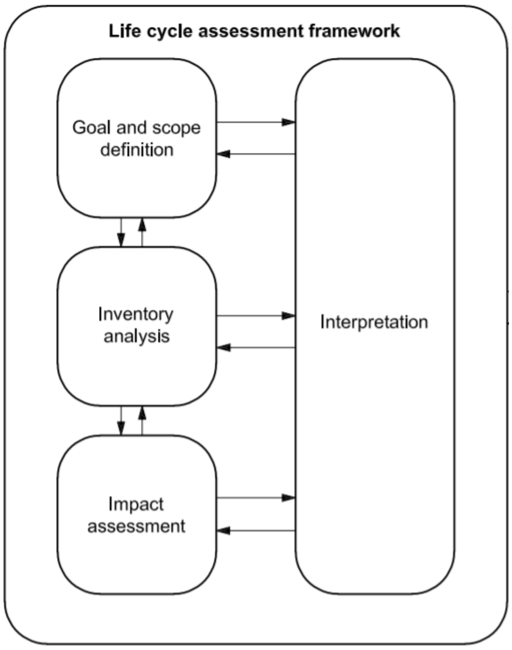


Figure 2.1: Phases of an LCA
(source: Normalization European committee, 2008)

Goal definition and scoping to define the product, process or activity and boundaries; **Inventory analysis** to identify material and energy flows, therefore environmental releases; **Impact assessment** to evaluate the potential human and ecological effects and the environmental releases of the inventory analysis and **Interpretation** to study the results of the inventory analysis and the impact assessment in order to determine the preferred product, process or service (SAIC and Curran, 2006).

LCA can also help to perform an environmental sustainability analysis of products and technologies to choose the best strategy among recycling, reuse, and other end-of-life recovery options analyzed in the CE approach (Del Borghi et al., 2020). LCA tools have been used broadly for analyzing waste management and are being currently used to evaluate the implications of waste valorization within a CE (Ward et al., 2016).

2.3.4 Life Cycle Assessment Applied to Agri-food

There are some authors that have already applied the LCA tool in the agri-food industry and it is very important to know why this was the selected approach and where it was applied.

Avadí and Fréon (2013) did a literature review that aims to illustrate the LCA framework by discussing its application to fisheries research. This review focuses on environmental assessment of fisheries and energy analyzes of fishing vessels and fleets. The goal is to identify challenges in fisheries LCA research.

Fedele et al. (2014) aimed to understand if an environmental assessment based on the recognized LCA methodological approach can support a single farm's comparative forecast evaluation of conventional and organic farming. The primary data used was relative to a short time period (a specific production year) and considers specific climate conditions (in particular rainfall conditions) from an

Italian farm situated in the Polesine area. They performed a comparative LCA, considering the conventional and organic production of barley and soybean.

Busse et al. (2017) gathered life cycle assessment data considering a recipe of roast beef and Yorkshire pudding to explore the energy use in food production and consumption. In order to explain how that sustainable cookery can have an impact on a sustainable food system, the author modeled seven possible interventions (like different cooking methods, ingredient change, and increasing appliance efficiency) in terms of impact on energy use within the context of this recipe.

Pérez-Neira and Grollmus-Venegas (2018a) used the LCA methodology to provide a comprehensive picture of the environmental impacts (energy and GHG) of the agri-food system associated to the cacao produced in Ecuador and exported to third countries for chocolate elaboration and consumption. The functional unit used was defined as the elaboration and distribution, until sales, of 1 kg of pure chocolate obtained from cacao cultivated in Ecuador. The same authors developed a work whose main objective is to analyze the energy metabolism and carbon footprint of peri-urban agriculture in the city of Seville taking into consideration the differences between production models and supply chains. The LCA methodology (cradle-to-consumption approach) was applied in three cases: two conventional farms that distribute their products through the local supply chain (wholesaler-retailer-store) and one community-supported agriculture initiative that grows organic vegetables and sells them directly to the consumer through alternative distribution networks (Pérez-Neira and Grollmus-Venegas, 2018b).

Liu et al. (2019) studied a sustainable pork meat value chain in France. The value chain includes a wide range of activities from feeding pigs to delivering the meat and related products to consumers. The goal of this case study is to increase the overall sustainable performance of the value chain. To generate the environmental criteria, a LCA software (Simapro 8.0.5) was used to map the theoretical pork production flows associated with each type of farmers with the goal of determining the number of environmental criteria that should be considered by each type.

After understanding the importance of building sustainable supply chains in the agri-food sector is important to understand how to achieve such chain. To do so the concept of mapping supply chain and the existing tools and methodologies to do so are going to be addressed.

2.4 Supply Chain Mapping

The supply chain mapping concept can be divided in two concepts: the supply chain concept, that was already described, and the map concept. Thus, first it is going to be defined what a map is. A map is a simplified model of the environment to communicate items of information (Muehrcke and Muehrcke, 1992).

A supply chain map is a simplified representation of the members of the SC and their interconnections together with some information concerning the entire SC to help the user interpret the map. (Wichmann et al., 2018). The focus while developing this map could be a particular use or user, or the opposite, covering all aspects of the supply chain structure. It can also be used as a type of value added tool (Gardner and Cooper, 2003). Moreover, these maps, range from a geographic vulnerability map to maps that have all the flows of parts represented starting from the region where they are sourced and everyone who is involved until the plants in other parts of the world that are dependent on them. In contrast, a geographic vulnerability map only illustrates the location of each supplier and what are their responsibilities in the supply chain (Sheffi, 2007, Wichmann et al., 2018).

Hence, supply chain mapping can be defined as the group of activities involved in the process of creating and maintaining a supply chain map, that includes acquiring and analyzing the necessary information and visualizing the results on the appropriate aggregation level (Wichmann et al., 2018). The maps can include organizations, flows, facilities, and/or processes. Then, a map can be represented in various different shapes and styles. Their purpose is generally strategic, and so, when creating a strategic supply chain map, it needs to be closely related to the corporate strategy. This last type of map can be an integral part of the strategic planning process or a tool for implementing the supply chain strategy (Gardner and Cooper, 2003).

There are a couple of practices to create a good map. One of them is to use standardized icons, that can come from academics, trade associations, or other sources. Conventions such as color-coding or symbol-coding business processes that connect organizations are also a good proceeding. There are also other conventions like the ones suggested by the creators of Value Stream Mapping and Process Mapping for the plant and process levels. However, there is not a common consensus about specific symbols for process mapping. Some supply chain maps look like computer flow charts, but others are more eclectic in their choice of symbols and presentations (Gardner and Cooper, 2003).

During the mapping process, it should be taken into account that, afterwards, the map will be spread out. That is why, it is important that maps are created in such a way that they are easily sent by e-mail or web distribution. On the other hand, the loss of control of who has access to the sensitive information, give the traditional paper a possible choice of dissemination. Thus, there are many security issues to be resolved regardless of the option chosen. This tool can be used as a solution to the problem of limited structural supply chain visibility (Gardner and Cooper, 2003).

However, there are some risks associated with mapping supply chains. Therefore, it is very important to have those in mind in order to make sure the goals that lead to the creation of the map are achieved. That is why the next chapter is about describing all the risks of mapping.

2.4.1 The Risks of Mapping

There are a wide range of possible ways to map a supply chain. For instance, a map can consider or be based on a database, it can reflect geographical relationships, or it can show each organization or a group of them. Moreover, maps can visually display all processes or just some of them or it can include none of them. Thus, the risks of supply chain mapping vary according to the amount of detail provided and the access that managers have to this data. However, not considering all the risks associated with mapping the supply chain can lead to very harmfully consequences, like losing competitive information, creating more competition or conflicts within the members of the chain (Gardner and Cooper, 2003).

The Data Availability Risk

One of the limiting factors is the existing difficulty to obtain information about supply chain participants and the relationships between each other. One possible solution is automating the data acquisition process so that supply chain maps are easily created and automatically updated, allowing the reduction of manual work (Wichmann et al., 2018).

However, firms must be careful about the amount of data they are providing to build the map, because if it is more data than what is needed, they are inadvertently giving away competitive information. Thus, the selection of material to be published in the map is a key process. On one hand, the brand shares data concerning suppliers and some of it competitors cannot easily know. Therefore, this can cause channel conflicts if a leakage of information occurs. On the other hand, the brand shares data throughout the supply chain that normally is easily accessible through individual retail information systems or through data collection firms. This is the case of including retail share data in a distributed map. Although it is a sensitive information, it may not be a critical risk. Moreover, all the data available in the map should be accompanied with the alternative data sources (Gardner and Cooper, 2003).

There are already short-term measures along the supply chain used within the company to adequately monitor the performance and improvements. Still, there is the need to gather inter-firm measurements and it is sometimes difficult to find appropriate information that is compatible with the IT systems of the other organizations (Melnyk et al., 2009).

The Complexity Risk

When creating the map, managers feel the need to incorporate many trading exchanges just because the data was available. This way, the map of the value chain can turn into a such complex map that it can compromise its strategic function. The complexity is caused by the high amount of relationships that increases exponentially when the value chain is extended beyond the first tier. This complexity makes it impossible to use the same map to guide strategic management decisions and at the same to help managing the supply chain (Farris, 2010).

The changes in customer requirements, competitive environments and industry standards are also sources of complexity. Moreover, supply chains are dynamic because they are constantly forming strategic alliances, engaging in mergers and acquisitions, outsourcing functions to third parties, adopting new technologies, launching new products/services, and extending their operations to new geographies, time zones, and markets. Therefore, these efforts to outsource, customize, innovate and make the supply chain more flexible and global makes it even more complex (Serdarasan and Tanyas, 2012).

However, it is important to understand the difference between necessary complexity and unnecessary complexity. The necessary complexity adds value to one or more entities in the supply chain and the customer or market is willing to pay for that. On the contrary, the unnecessary complexity is not beneficial for any entity involved in the supply chain and has an additional cost. This way, manager should eliminate or reduce unnecessary complexity and only manage the necessary complexity

(Serdarasan and Tanyas, 2012).

Level of detail Risk

A strategic supply chain mapping is a broader supply chain map that requires more data throughout the entire supply chain. This map is called a ”macro map” and gives an overall view of the supply chain at the industry level, so that it can be, afterwards, used to explore more detailed mapping of concentrated areas (Farris, 2010). This ”macro map” will give all supply chain members a perception of their roles and their relative importance in the network, which can be different than the ones they thought they had. This map can make suppliers or customers disappointed, but they will know specifically where they stand towards the company, for instance, in terms of specific ratio of volume of business. It can make suppliers or customers more motivated to increase or hold on to their market share (Gardner and Cooper, 2003). Nonetheless, there is a risk associate with the disclosure of the geographical context and the geolocation of a company’s headquarters since it gives an idea of the geographical vulnerability (Wichmann et al., 2018).

Managers should have in mind the scope of the map, which variables should be analyzed or omitted and the key elements or the ones that represent specific situations while designing a map (Gardner and Cooper, 2003). Moreover, there is a minimal amount of information needed to describe a supply network, like all the entities and the connections between them (nodes and links). It is also important to know which materials, parts or services are provided by each entity and the end-product that benefits from it (Wichmann et al., 2018). However, in the end, these maps have a crucial role in solving the visibility problem.

2.4.2 The Visibility Problem

One important aspect of mapping the supply chain is to guarantee visibility. There are many definitions of supply chain visibility (SCV), but almost all are related with the ability to collect and analyze distributed data to formulate recommendations. Therefore, SCV gives updated information to key customers, suppliers and partners so that the efficiency of the SC can be improved. The goal of SCV is that all SC partners have access to the right information at the right time. From this point of view, SCV enables to share real-time information with key customers, suppliers and partners in order to improve SC efficiency. This concept can be defined according to two different perspectives: tactical and strategic (Zhang et al., 2008).

The tactical supply chain visibility describes the visibility of material flows, finance flows (for instance, transactions related to global trades), inventory level and availability of production capacity and resources in the supply chain. Due to the great number of partners that a supply chain has, compliance can be achieved through cooperation and collaboration. On the other hand, SCV has also implications in the strategic decision making for the entire organization. This view of SCV is about the evaluation and reshaping of the resource network according to the changing business environments. Thus, this perspective focuses on creating cooperative partnering relationships and collective decision-making behaviors among supply chain entities (Zhang et al., 2008). However, there is a lack of a strategic perspective of the supply chain since senior managers do not see the benefits that SCM can generate when it is better measured and recognized. In order to make the most of SCM, it is important to have a more refined alignment of functional areas such as operations, logistics and supply management, so that true global perspective is created (Melnyk et al., 2009).

Managers and researchers should be able to interpret the behavior of the supply chain in a more complete way in order to define interventions that are more likely to be effective (Choi et al., 2001). According to Carter et al. (2015), each entity tries to manage its operations and a portion of the supply chain upstream and downstream (within its visible range) to increase performance for its benefit. For instance, if the entity is a distributor, the focus would be on choosing the best manufacturers on the upstream side and expanding its customer market downstream. According to these authors, the visibility boundary is based on the knowledge of each entity about the existence of another entity, its location, and the activities that occur there. Beyond the visible range, all entities need to accept what happens there because the visibility is limited.

This lack of visibility has a negative impact on managing the supply chain because it is accompanied by knowledge shortage, a loss of control, and distrust. This problem also enhances risks in the efforts to create a sustainable supply chain. However, examining the environment of the entities involved is a way to reduce uncertainty toward sustainability-related issues. The same happens with finding ways to extract, collect, and share individual knowledge from different sources at different production stages in the supply chain which might create a greater supply chain visibility (Reynolds, 2017). Moreover, by increasing the SCV, managers can better identify lean wastes, which are defects, overproduction, inappropriate processing, unnecessary inventory, unnecessary motion, transport and waiting. Applying this concept to the agri-food industry, SCV holds the capacity to constantly detect food loss and waste and the hotspots where they occur. After having considered the advantages and disadvantages of mapping, it is time to study tools to map an AFSC (Wesana et al., 2019).

2.4.3 Agri-food Supply Chain Mapping Tools

In order to build a supply chain mapping tool, it is important that a preliminary analysis of the processes is undertaken so that it is possible to, afterwards, gather a detail recording of all the items required in each process. Every step needs to be categorized in terms of a variety of activities (operation, transport, inspection and storage) and during each activity some indicators need to be measured, like distance moved, time taken and number of people involved. This will be the base to create a simple flow chart (Hines and Rich, 1997).

The Value Stream Mapping tool (VSM) creates a reliable and systematic map of hotspots to facilitate subsequent food and nutritional loss measurement and reporting. Thus, this last tool will make mitigation approaches possible along the food supply chains (Wesana et al., 2019).

VSM is a diagnostic technique that is based on the lean manufacturing principles. Its main goal is to distinguish between the value-adding and non-value-adding activities in the value stream in order to eliminate wasteful activities and align the production with the demand. Wasteful activities are all activities that, from the customer perspective, do not add value to the supply chain. This VSM should include everything from raw materials to end-consumer so as to evaluate the overall efficiency by determining performance indicators (Brunt, 2000, Waldron, 2009).

There is a wide range of lean techniques that can be applied. The most common one, is identifying and reducing or even eliminating the seven lean wastes. However, a just in time methodology and/ or the 5S (sort, set in order, shine, standardize and sustain) methodology can also be applied. These strategies can lead to a continuous improvement of the system (De Steur et al., 2016).

Considering the case of agri-food, the lead time is one of the most important indicators, because when it is decreased there is an improvement in the performance of the demand chains and better competitive capabilities of the actors. This can be justified by the perishable food representing one of the main flows of this type of supply chain. This type of food needs to be delivered to the consumer at a considerable level of freshness, otherwise it will be discarded as waste (De Steur et al., 2016).

For the purpose of using VSM successfully, it needs to be accompanied by other tools, like current and future state maps so that it is possible to identify and eliminate wastes by illustrating performance improvements (De Steur et al., 2016). The following figure shows a general example of a value stream mapping (see Figure 2.2). Normally, each process box has a data box to show typical lean measurements like cycle time, change over time and value-adding time. In Figure 2.2 the data box is below each process box (Waldron, 2009).

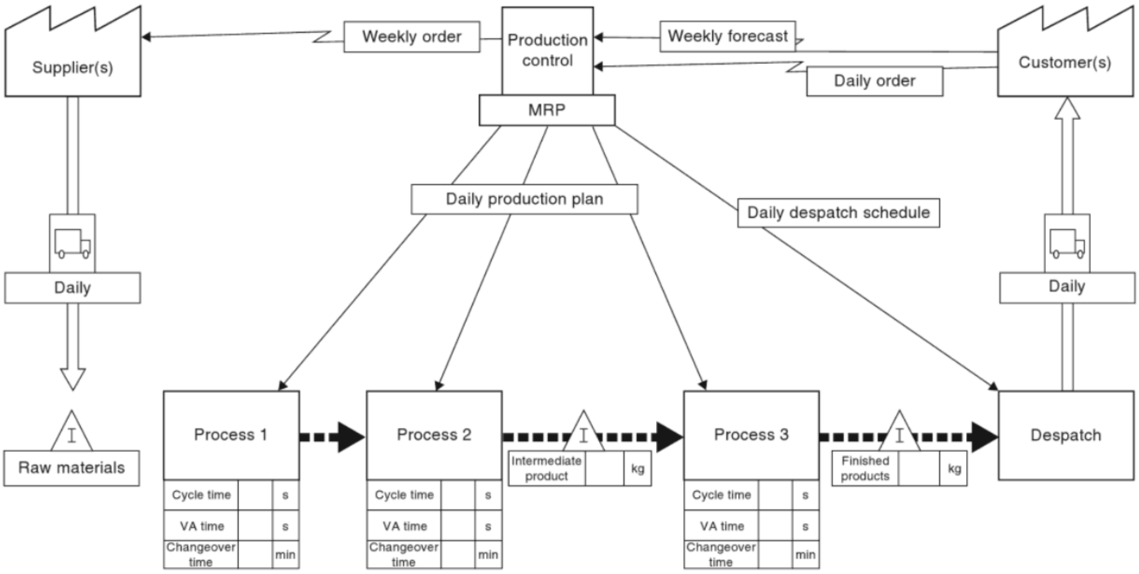


Figure 2.2: General example of a value stream map
(source: Waldron, 2009)

In case of accumulating inventory between processes, the situation is expressed in the map through a ‘warning triangle’ in the location of the map where the flow is interrupted and how much inventory is involved in terms of quantity and/or number of days of production (Waldron, 2009).

Simulation can be used as a complementary tool to VSM since there is a need for justifiable and practical evidence that shows the impact of the lean practices adopted (De Steur et al., 2016). Simulation is the process of designing a model of a real system and conduct experiments with this model to realize the behavior of the system or to assess various strategies. Simulation gives immediate assessment of proposed changes to the model in a cheap, quick and easy way Suhadak et al., 2015. Furthermore, simulation can be applied in unique and complex systems, like the agri-food industry. Hence, it is important to make sure that it is possible to incorporate simulation models into the VSM methodology in the beginning of the study (De Steur et al., 2016).

As a result, VSM provides the current state map, which is the base model, where the data, new ideas and strategies will be tested using simulation. Afterwards, when all simulations are completed, the VSM is used to design the future state map, which is the one that incorporates the new ideas and improvements. This way, simulation models allow managers to understand the effects before and after implementing a change which includes the impact of layout changes and resource reallocation, without huge investments. In most companies, especially small companies it is difficult to introduce a new concept, but if simulation is combined with the visual map of VSM, it is easier for the workforce to understand it and so the adoption is faster and there is less resistance to change (Suhadak et al., 2015).

After understanding the importance of the VSM tool, the next phase is to understand how to implement it step by step in order to develop a map.

How to create a value stream map

Wesana et al. (2019) proposed a methodology to map a AFSC that was afterwards applied to the dairy supply chain of yogurt and UHT milk. The first step of this methodology consists in explaining the scope of the study, which includes the period of the data collection, the material type, the destinations and the boundaries of the data collection. If there is some other related issues, they also should be explained. Then, the next steps are to gather data through interviews with different employees that work at the different supply chain levels and to observe the processes to confirm the answers. The observed situation takes precedence in case of inconsistency. These interviews could be divided in three main parts. The first part involves general information about the stage of the supply chain, process name and constituent step. The second part gathers information related to cycle times (i.e. time a process takes from start to finish), waiting or non-value adding time and the number of operators managing a process. The third and last part of the interview is to collect more details about losses and waste that occurred along different stages of the supply chain. After receiving all this data, researchers are able to create a “current state map” describing the present situation along the supply chain with an emphasis on steps, processes and occurrences of food loss and waste (FLW). Lastly, lead time is also calculated using cycle time and waiting/non-value adding time observed by following operations along the supply chain. The authors used the load tracking method developed by the Food and Agriculture Organization (FAO) to measure the magnitude of FLW. According to this method, the quantity of milk or its products needs to be recorded before and after an activity, and so the difference between those quantities is the magnitude of FLW.

To measure the nutritional value embedded in FLW, the macro-nutrients present in the food need to be assessed, like energy (kcal), protein (g), fat (g) and carbohydrates (g), as well as the micro-nutrients (mg or µg), which are, for instance, calcium, phosphorus, magnesium, potassium and sodium. In Figure 2.3 shows a state map, made by these researchers, outlining the production processes for yogurt and UHT milk in the dairy chain. The program used to design the current state map was Microsoft Visio 2016.

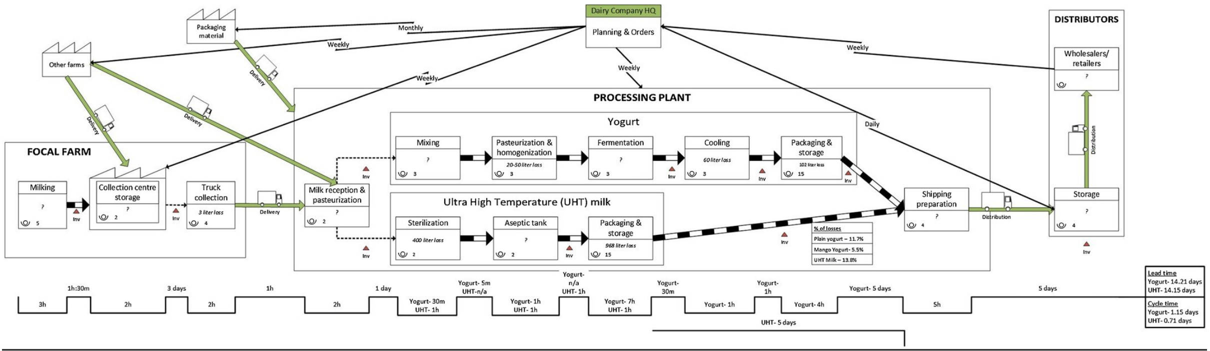


Figure 2.3: Current state map of the dairy supply chain of yogurt and UHT milk
(source: Wesana et al., 2019)

2.5 Developed Cases Regarding Mapping Agri-Food Supply Chain

There are some researchers that did not follow any of the tools presented previously. Instead, they have created their own methodology to build a map for a specific supply chain. On this section, it is going to be provided two of these methodologies that were presented in case studies. The first one is a methodology to map the environmental and technological performance, which is very important because environmental management can be very challenging due to information gaps. For instance, the operational data on carbon management is not often gathered, communicated and acted upon. There can be different reasons why companies choose to measure the environmental performance. These may be due to the need that authorities and external stakeholders feel to control and monitor the company. It also allows the company to set goals, control and monitor product and processes performance, which leads to improvements in the supply chain (Kurdve and Wiktorsson, 2013).

The second methodology is a value chain analysis to evaluate the system functionality, inefficiencies and potential opportunities for policy interventions. A value chain analysis consists in mapping all people, products and chain profiles. It also represents them in a spatial and temporal dimension (Alarcon et al., 2017).

2.5.1 Mapping the environmental and technological performance

Midžić-Kurtagić et al. (2010) used a mapping methodology to map the environmental and technological performance of food and beverage sector in Bosnia and Herzegovina. This methodology could be divided into four steps. The first one was the selection of indicators and collection of data to describe the structure and the socio-economic status of the industrial sector. In other words, the first step involved collecting information about the process and the capacity characteristics of installations in the food and beverage sector. This information was afterwards compared to the reference installations in the EU and other countries. The goal of the economic assessment was to analyze the aspect of economic stability and the potential of investing in improvements.

The second step was the review and analyzes of national legislation, environmental standards, and international obligations related to this industrial sector. There is a comprehensive legal framework that regulates the food and beverage sector, including specific technical and technological requirements, for instance, for pollution prevention and control and for food and health safety. Besides reviewing this legal framework, the authors also considered policy papers such as Strategy for Environmental Protection and international treaties about obligations that Bosnia and Herzegovina ratified.

The third part was the selection of indicators and collection of data to describe environmental performance of this industrial sector. The environmental performance of food and beverage companies was assessed using input-output operational performance indicators, giving special attention to resource consumption and the emissions generated. The authors relied on environmental monitoring reports of the individual companies taking also into consideration the Activity Plans for Reduction of Emissions and Compliance in order to analyze the environmental permitting procedures. However, because there was not enough available information, environmental audits in a number of selected companies were conducted by the authors. The last step was the collection, review, and analysis of how companies employed the Best Available Techniques. The Best Available Techniques are a group of requirements that operators are legally obliged to use to prevent or minimize the negative impact on the environment.

2.5.2 Flow charts, temporal and geographical mapping

Later, in 2017 (Alarcon et al., 2017), some authors proposed another methodology to map the beef, sheep and goat food systems in Nairobi. The goal of this map was to create a framework for policy making and to identify structural vulnerabilities and deficiencies. This methodology starts with the study area and selection of participants. The authors interviewed 25 focus groups, like key officers of the wholesaler meat markets and major processing companies supplying Nairobi city, and 21 key informants, who understood the overall pattern and functionality of the market or represented a particular group of people difficult to access. They also collected secondary data on animal movements and did some individual interviews with nineteen abattoir managers and six traders.

The second step of the methodology was the data collection. To do so, the authors used a combination of two methods. The first one was through open-ended questions and the second one was by creating flow charts using input of the participants until a consensus on the type of people, products, locations, flows and quantities, was achieved. This was an interactive process, so the open ended questions helped clarifying the flowchart and the flowchart led to new questions. Furthermore, movement permits of animals arriving at these markets the year before were consulted and recorded when available.

The third part was the analysis of the data to identify emerging themes that describe an activity or a specific profile in the chain. The authors used templates in order to organize these themes into meaningful sections and to create flow charts. This way, it was possible to recognize operational similarities between the food system nodes. Then, combining data from all the templates, the authors created system, temporal and geographical maps.

Using people and product profiling information, they created flowcharts of the different animals, products, people and places involved in every market or company, and the movements between places. All flowcharts were combined with the themes in order to create system maps that indicate the chain flows, the people and products presented in each node. In Figure 2.4 is the flow chart of all local terminal markets operating in Narobi made by the researchers. In this picture, the circles indicate commodities traded, arrows represent the product flows and the ones that are dotted are the rare flows, boxes indicate people or places and the dotted boxes indicate occasional flow through. Percentage shown in meat trader box correspond to percentage of traders in each category.

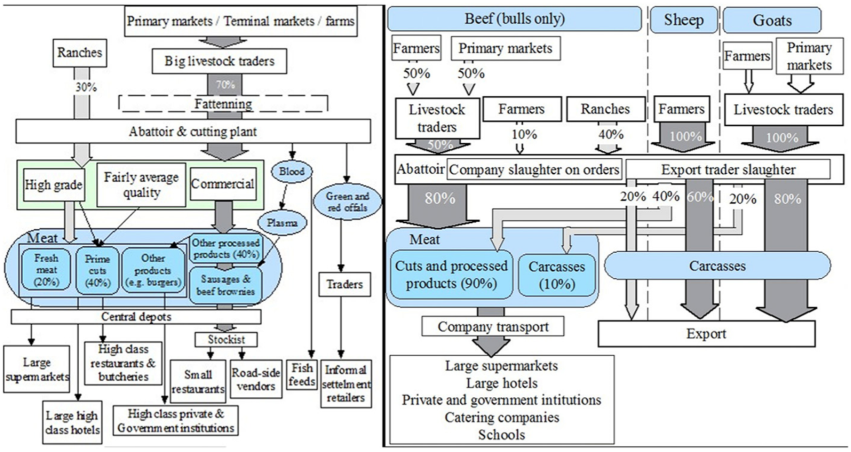


Figure 2.4: People and product profile for three large processing companies
(source: Alarcon et al., 2017)

Temporal mapping was done by analyzing the contribution of markets during an entire period in order to show seasonal variation of routes and animals traded. The movement permits were categorized by the routes identified in the geographical mapping. In Figure 2.5 is a temporal map that shows the amount of beef, sheep and goat supplied to a large processing company grouped by high and low season. Geographical mapping showed the main physical paths for animals and carcasses to reach different markets and abattoirs. Thus, the analysis of geographical supply routes leading to each terminal market showed a unique geographical pattern of influence based on the combination of main routes used. In Figure 2.6 is a geographical map indicating the source of ruminants for one of the markets supplying Nairobi.

Through an analysis of the results, researchers were able to identify key structural system deficiencies and vulnerabilities. The last step was the data validation of the initial results by people who have knowledge of the ruminant meat food systems, like non-profitable governmental organizations and market owners (Alarcon et al., 2017). Even though mapping the AFSC enables us to create a sustainable supply chain, measuring it is essential to make sure that the supply chain is sustainable.

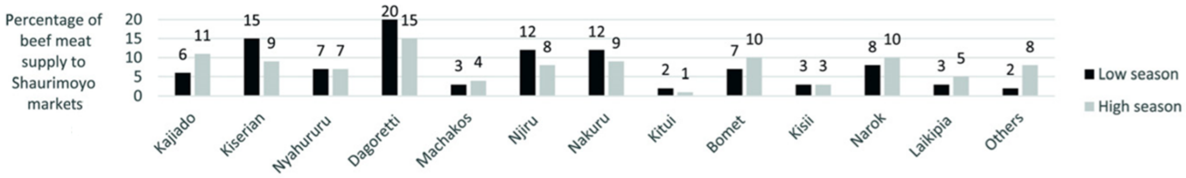


Figure 2.5: Number of beef, sheep and goat supplied to a large processing company (source: Alarcon et al., 2017)

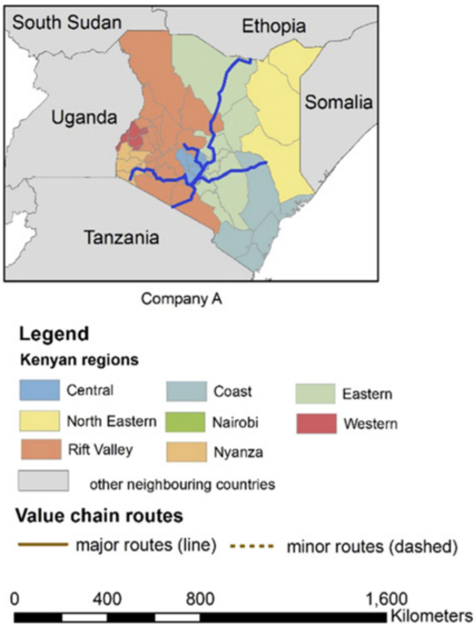


Figure 2.6: Geographical map indicating source of ruminants for one of the markets supplying Nairobi (source: Alarcon et al., 2017)

2.6 Importance of measuring a food supply chain network

As mentioned, food loss and waste have many negative economic, environmental and social impacts. From the economic point of view, there is a big opportunity when reusing the waste generated through the agri-food value chain in other independent processes, or even in different industries. However, this implementation is not a common practice because it needs a very high level of cross-firm or cross-industry collaboration that is not always possible (Ellen MacArthur Foundation, 2013). Moreover, the FLW represent a lost investment that reduces the farmers' income and increases customers' expenses.

Regarding the environmental impact, the consumption of virgin material has a wide range of consequences, including unnecessary greenhouse gas emissions, like methane and water, and land productivity. This situation leads to diminished natural ecosystems and the services they provide (Cannavò et al., 2019).

Also, agri-food is a sector that has crucial implications on human capital employment and nutritional security, which represent the social implications (Tsarouhas et al., 2015). The reduction of food waste has an important contribution to the three components of sustainable development (economic, social and environmental), however this does not mean that all measures that are implemented to reduce the food waste have a direct effect in the sustainable development principles (Cannavò et al., 2019).

To achieve an adequate measurement of the supply chain performance and to understand in what extent a supply chain is meeting the end-user and stakeholders' requirements in terms of sustainability, relevant performance indicators should be used. That's why an effective Performance Measurement System (PMS) should be in place.

2.6.1 Performance Measurement System

According to Neely (1998), a PMS is a system that allows informed decisions and actions since it quantifies the efficiency and effectiveness of previous actions across acquisitions, collation, sorting, analysis, interpretation and dissemination of relevant data. A PMS can be also defined as a system that allows firms to control the key performance indicators of products, services and production processes in the appropriate time frame (Rosenau et al., 1996).

There are three main aspects that Performance Measurement Systems need to incorporate to analyze the success of the supply chain (Van Der Vorst, 2005). The metrics that are applied in performance measurement and improvement really need to express the essence of the organizational performance. A measurement system should make the assignment of metrics easy so that each measure is, for sure, allocated to where it is most appropriate. Measurement goals must represent organizational targets and metrics and should reflect an equilibrium between financial and non-financial measures. These measures can be related to strategic, tactical and operational levels of decision making and control (Gunasekaran et al., 2004).

Hence, PMS gives information to the decision maker about whether they are achieving the goals, if the customers are satisfied or what improvements are needed. In order to do so it is mandatory that the company has access to the right information when asked (Aramyan et al., 2007). That is why choosing the right Key Performance Indicators (KPIs) is essential.

Implementing a PMS in the AFSC and so choosing the right KPIs is a very challenging process because the food industry is an interconnected system made of wide range of complex relationships due to alliances, horizontal and vertical cooperation and forward and backward integration (Van Der Vorst, 2005).

2.6.2 How to choose the KPIs

Performance indicators are the characteristics of the process, product or service that need to be evaluated. The performance indicators should be chosen taking into account the business objectives of the organization and the fact that they will be used to compare the efficiency and effectiveness of the system with the target value or norm. Therefore, to establish them it is necessary to have a deep understanding about what is important and needs measurement (Aramyan et al., 2007).

In order to have a complete and accurate set of KPIs there are some characteristics that they all should satisfy. These characteristics are being inclusive since they should cover all aspects and processes of the supply chain, universal in order to be possible to compare them under different operating conditions, measurable in the sense that needs to be quantitative (Beamon, 1998).

It is also very important to have the following aspects in mind while defining the KPIs: using standardized definitions, rules and calculations that can be applied throughout the entire company. The KPIs need to be supported by appropriate individual incentives and contribute to employees' motivation (Strelnik et al., 2015).

2.7 Conclusion

Throughout this chapter the problem under study was contextualized with a theoretical perspective due to a literature review regarding sustainable supply chain and methodologies to transform, manage and measure this type of supply chains. Thus, taking into account the information presented in this first section it is concluded that sustainability goes far beyond one single company and it is necessary to consider the entire supply chain. Afterwards, this research was applied to the AFSC by first explaining what is one and then how to create a sustainable agri-food SC.

One of the most important findings of the third section was that, among other approaches, circular economy and life cycle assessment are efficient strategies to transform an agri-food supply chain into a sustainable one. These methodologies were described and case studies where these approaches were successful applied to the agri-food sector were presented. However, having an understanding of the entire supply chain is helpful, not only to make it easier to implement these methodologies, but also because makes it easier to detect the hotspots and come up with solutions to minimize or eliminate them.

This is why the section that followed was about the idea of mapping a supply chain. This way, each company knows its role in the system and can better define a strategy taking also other companies into account, as well. Then, some tools used to map an AFSC were described, as well as some methodologies that have been used in other case studies. After analyzing these studies, the conclusion that there are many reasons that lead to mapping the supply chain, and so there is a wide range of possible maps that can be created according to its goal was reached.

However, it is crucial finding a way to make sure that the transformations done to the supply chain are getting the expected result. Which leads us to the last section. In this section was concluded that in order to achieve a SAFSC it is mandatory to have a performance measurement system to evaluate the supply chain in an economic, environmental and social point of view.

The next chapter will connect all the information gathered in the literature review in order to establish a solid base from which a general tool to measure the AFSC will be built. In the next chapter is going to be explained all concepts related to AFSCs and FLW in such a way that other researchers are able to apply this knowledge on their specific AFSC and detect its hotspots.

Chapter 3

Mapping Agri-Food Supply Chains

This chapter aims to develop a methodology to create SAFSCs and then measure how sustainable they are. The sustainability will be measured by detecting where the most common hotspots are located in order to afterwards define KPIs to measure the impact of those inefficiencies. With this goal in mind, the structure of this chapter is divided into four main sections. In the first section a general AFSC is explained, which includes the representation and description of all entities and flows. In the second section, the most important terms are defined so that an analyze of these supply chains is possible. The third section will discuss the importance of the reverse flow, which will allow us to construct a more sustainable general AFSC and then presenting it. Finally, the fourth section is about where the hotspots normally are located, how to measure those inefficiencies and how to improve them.

3.1 A General Agri-food Supply Chain

In order to better detail the AFSC, a general framework is taken as a starting point (see Figure 3.1).

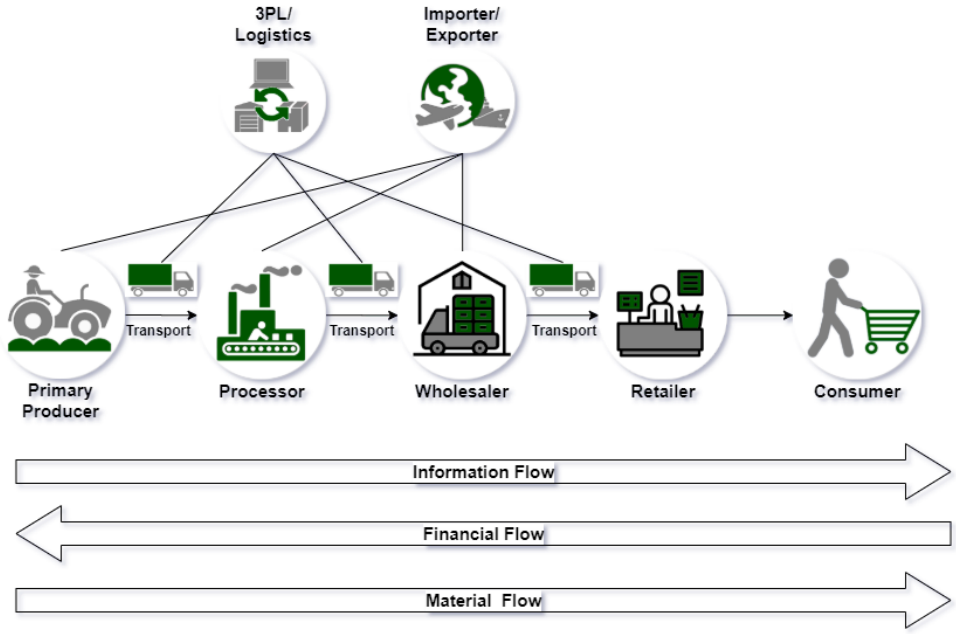


Figure 3.1: Agri-food supply chain network
(adapted from K.Tsolakisa et al., 2014, Jaffee et al., 2010)

First, the involved entities are described and their roles analyzed. Afterwards the material, financial and information flows involved are characterized and their importance to a successful management of the supply chain discussed. This description is based on the one proposed by Ricardo Martinez (Martinez, 2019).

3.1.1 Description of Entities

Primary Producers are the input of this supply chain. They are responsible for the growth and management of the food. This production process varies accordingly to the product in hand, but includes all activities related to the harvest, handling and storage of food products before they move to the processing stage. The primary production encompasses agricultural activities, aquaculture, fisheries and similar processes resulting in raw food materials. Any level of processing of raw food products does not fall within this stage of the supply chain. Primary producers' activities are very risky because they are subject to uncertainties, for instance, pests, weather conditions and market volatility that cannot be controlled. (Dani, 2015, Verdouw et al., 2010, Martin and Osterling, 2014).

Processors are responsible for transforming the raw materials into the state in which the product is ready for consumption. The processor's work changes accordingly to the final product that is going to be sold, but often include starting activities as washing, sorting and grading the materials received. This entity is able to expand the range of products available to the consumer. They shape the conditions in which the product is delivered to the customer by the other market participants. They often also include packaging and labelling activities. Within the packaging activities they ensure a proper handling of the products and the labelling activities have the goal to add product-related information that is needed for further processing such as article code. In sum, the processor creates a market for the primary producers (Verdouw et al., 2010, Bezat-Jarzębowska and Rembisz, 2016).

Wholesalers are responsible for sorting, selecting and boxing the final product according to the retailer's requirements. Therefore, this entity is accountable for assuring quality and consistency of the product. They tend to have only one site where they can source different kinds of products at the same time in order to reduce the risk of delivering just part of the products needed by the retailer. This allows retailers to reduce coordination costs by dealing with fewer intermediaries (Hernandez et al., 2006).

Moreover, wholesalers are responsible for receiving, warehousing, dispatching and transportation, which often involve one of three different distribution modes: direct delivery, delivery via intermediate storage in a distribution centre and cross-dock transshipment. The direct delivery is when the product is delivered directly to the retailer without the involvement of any intermediary. The Distribution Centers are normally the ones responsible for supplying the food retail stores where temperature control is a key factor as this affects the food products' quality (by influencing the level of quality degradation) and product safety (by influencing the growth of potentially harmful bacteria) (Akkerman et al., 2010, Verdouw et al., 2010). For cross docking, the process is about cross-exchanging goods between delivery trucks from a variety of carriers that dock in the entrance of the transit terminal at the same time and empty delivery vehicles which are ready to be loaded with outgoing goods. However, there are some requirements in order to make sure that the process runs smoothly. For instance, there is some information that should be given, in order to control the operation factors, like the minimum and maximum order volumes with the suppliers. Also, a high reliability is required, and so no stock buffer is needed between the manufacturer and the branch. It is very important that the cross-docking platform can deal with high volumes in small amounts of time (Gleissner and Femerling, 2019).

Retailers have the role of delivering the final product to the final consumers, which can be done by a wide range of channels, like supermarkets, specialized fruit and vegetables shop, market and street trade, and food service providers including restaurants, hospitals and caterers (Bijman et al., 2006, Verdouw et al., 2010).

Lastly, **the consumers** are the final entity that possesses the product and so are the ones who consume the product. Therefore, they are the ultimate beneficiaries of the entire supply chain (Cao and Mohiuddin, 2019).

The transportation, management and logistics between entities can be helped by **Third party logistics (3PL)**, which are responsible for supplying the right products to the right consumers in the right quantity. Therefore, they manage all or part of the client's logistical requirements. These requirements include controlling a wide range of activities, like transportation, inventory optimization, warehousing, order fulfilment and the integration of these and other functions. There are also ten key services that the 3PL providers offer, which are strategic capacity; logistics expertise; network analysis; mode and load optimization; cost-containment strategies; vendor compliance management; system support; actionable business intelligence; best practice sharing, and risk profile reduction (Patil and Dolas, 2015).
This network can also receive a flux of products from the **import traders** or have an output of products to the **export traders**.

3.1.2 Description of Flows

The above described entities are linked by logistical, financial and technical services. These services, in turn, are supported by three flow types: the information flow, the financial flow and the material flow.

The material flow is the physical product movements from input suppliers to the end customers, going through all entities previously described.

The financial flow is about the credit terms and lending, payment schedules and repayments, savings and insurance arrangements. This flow goes upstream the supply chain because the entity that receives the product will buy it from the previous one.

The information flow coordinates the material and financial flows and has the same direction as the product flow because it is about the products that are being transported throughout the supply chain (Matopoulos et al., 2004, Jaffee et al., 2010). The amount of information depends on the supply chain's product and the structure of the network. The more extended the network is, the larger is the number of entities involved and so there are more sources of data, which leads to a larger flow of information. There can be identified different kinds of information shared in an AFSC. In this supply chain, the perishability nature of the products demands efficient product flows supported by adequate information. In order to achieve this high level of efficiency, there are two different types of information that can be distinguished

in the information flow: product-related and logistics-related (Matopoulos et al., 2004, Jaffee et al., 2010). The product-related information only includes data connected to the product. Examples of this can be quality data, product characteristics and attributes, handling processes controlled throughout the SC. On the other side, logistics-related information refers to the data that is necessary to be managed in order to propose efforts towards more efficient transportation methods between farmers and end consumers. Order and transportation-related details, as well as harvest estimates, like yield predictions and harvest dates are just possibilities of this type of information (Matopoulos et al., 2004, Jaffee et al., 2010).
It is often the case that there is an information gap among entities of the AFSC which is a major fragility of the agri-food industry. This can be caused, either by the lack of willingness to share information, or by failing to do so. The notoriety of the information flow has grown due to the increased need from governments and retailers to deal with food safety issues, and/or to improve performance across the supply chains (Matopoulos et al., 2004, Jaffee et al., 2010).

3.2 Agri-Food Supply Chain's key terms

In order to map a SAFSC it is important to understand some key concepts like Expected Product; Food Waste; Residue; Subproduct and Coproducts. This is going to be performed next. The descriptions given to these concepts were based on the developed work under the Mobfood project where the input of relevant companies of the portuguese agri-food sector were taken into consideration (PPS7, 2019). Also, for some definitions, adjustments were proposed considering other authors.

An expected product is the final product that can be consumed and commercialized. This includes all products provided within the required specifications, not only to the priority market, but also to the secondary market. Contrarily, the **unexpected product** includes all products that are not as predicted because of accidents, for instance, during transportation, contamination or handling. Also includes all products that are obtained during production but are not intended to be immediately commercialized (like pig ears). Therefore, the unexpected products are produced due to the incapacity of securing quality and other production conditions or the unintended creation of products during production that are not going to be commercialized (PPS7, 2019).

Food waste was defined by National commission against food waste (CNCDA, 2018) as any substance, transformed product, partially transformed product or product that was not transformed at all and whose destiny is to be consumed by humans or that has a high probability to be consumed by humans, but that the owner gets rid of it or has intentions to do it viewing it as residue.
However, the CNCDA acknowledges that there are some exceptions to this definition like the donation to human consumption (Redistribution) and animal feeding. The *Fusions* Manual (Stenmarck et al., 2016) also considers that if this product is used as biological raw material or for biochemical processing is also not considered food waste. The biological raw material includes the production of plastic with a biological nature or other traditional products, like leather and feather. The biochemical processing is the usage of food components to extract molecules for chemistry applications, for instance chemicals derived from

fruit peels (PPS7, 2019).

Food loss includes all products that are not commercialized as expected but are still fit to human consumption. These products can lead to financial losses and quantity losses (PPS7, 2019). The FAO (2019) also added that the food loss results from decisions and actions by food suppliers in the chain, excluding retail, food service providers and consumers.

A Financial Loss occurs when the product value is reduced, but it is going to be integrated again in the normal flow in the same conditions (like the products that are in discount since the expiring date is near). A Quantity Loss happens when it is not possible to deliver the product in its current conditions but it is still good for human consumption. The most common reasons why products are not fit to human consumption are the explicit expiration date or accidents specially while handling the products.

A coproduct is a product that was not intended to be obtained for commercialization but can still be consumed by humans without any additional processing. This way, when the resultant product is an unexpected product but it is still fit for human consumption, it will fall in one of two categories: a Coproduct or a Quantity Loss. An unexpected product is considered a Coproduct when there is no need for any additional processing, otherwise it will be considered a Quantity Loss. As additional processing it is meant any activity that changes the current state of the product.

The products designated as coproducts or quantity loss can be redirected towards added value activities in secondary markets since they are fit for human consumption. If that occurs, the products will enter the flux of a new entity through production and transformation. If this is not the case, they may also be redirected to ends excluded from food waste (PPS7, 2019).

A subproduct is any product, substance or object that had resulted from a production process whose main goal is not its production. Only products that are not able to be consumed by humans are included in this category or products that even though are fit for human consumption, are excluded by humans (PPS7, 2019).

The APA (Agência Portuguesa do Ambiente, 2015) definition also adds that the product needs to follow all relevant requirements in the environmental and health protection point of view so that it does not have any global impact on those areas while being used. Also, there is a need to previously make sure that the product will be used. However, there are also exceptions like it does not include residues that were excluded in the context of general regime of residue management. The same happens with the residues that were generated during the production (for instance, empty packages) or any substance or object whose referral is to energy recovery activities.

All products that entities want or need to get rid of, because of not being fit for human or animal consumption, are considered residues. Therefore, a product that is not commercialized because it is not what was expected or because it cannot be used for human consumption but is still good for animal consumption is a Subproduct, otherwise it is a **Residue** (PPS7, 2019).

3.3 The Environmental Problem

To produce the desired product, pollutants and other byproducts are produced along the supply chain process. Byproducts are everything that is produced during the manufacture or processing of a product. For instance, packaging is used to protect the products from damage, however once they are consumed, the package is no longer desired. That is why, a proper management and awareness of the environmental implications of logistics activities is crucial to significantly reduce the negative impact of those activities.

Traditional logistics systems, like the framework showed in the beginning of this chapter (Figure 3.1), do not usually address environmental problems and are only focused on economic targets (minimizing costs and maximizing profits). In contrast, a sustainable responsible logistics approach takes into consideration another target to the system: minimizing the total environmental and social impact. New social and environmentally responsible practices, on one hand, may be more expensive, but on the other hand, the expanded market share may bring more profits to offset the added costs. One example are the recyclable pallets because even though using them will add burden to the logistics system, it can save money in the long run. However, sometimes social and environmentally responsible practices only add costs to the operation and reduce productivity, for instance avoiding importation of food overseas. Logistics managers need to consider and weight all the options available and select the ones needed to achieve the firm’s social, economic and environmental goals. The challenge that the managers need to face is in justifying the potential contribution of social and environmental elements such as emissions reduction and fewer miles driven, in terms of the benefit to the firm and to society (Wu and Dunn, 1995).

The environmental legislation has shown a clear tendency to move towards making companies increasingly responsible for the entire product’s life cycle. This means being legally responsible for the product’s destination after delivering it to the customer and for the impact on the environment. A second aspect is about raising ecological awareness of those who expect a reduction of the companies’ negative impact of their activities on the environment. This has generated actions by some companies in order to be able to communicate an institutional image to the public as being “Ecologically correct” (Lacerda, 2002).

Many trade-offs can be made to reduce the environmental impact of logistics activities. However, there are two important logistics issues that cut across functional lines that needs to be discussed in detail: the reverse logistics and the recycling entity. This approach deserves a further investigation due to its potential impact on the environment. The following discussion is focused on reverse logistics as an integrative activity in the logistics system and the recycling entity as the responsible for the complementary activities to support the reverse flow.

3.3.1 Reverse Logistics and Recycling Entity

The reverse flow is the process of planning, implementing and monitoring the flow of resources, semi-finished and finished goods and the respective flows of information and financial from production until consumption. The ultimate goal is to collect, sort, package and expand items that were used, damaged or obsolete in order to regain their value or to proper dispose the wastes. Reverse logistics flow includes the shipments of packaging waste, recyclable packages and customer returns. This definition also incorporates all efforts to reduce these reverse flows because it means reducing the total amount of waste in the system (Pourmohammadi, 2009).

The type of activities carried out during the reverse logistics process depends on the material type and the reasons why these materials have entered the process. They can be divided into two groups: products and packages. In case they are products, the reverse logistics is about repairing, recycling materials or product returns by the customer (Pourmohammadi, 2009).

In the case of packages, even though returnable packaging adds logistics costs due to the extra handling equipment and storage space, the total cost of the supply chain is reduced because returnables can be used many times and the disposal is minimized. When environmental costs are included in the total logistics costs, using returnables is normally cheaper (Coelho et al., 2020).

The tenets of reverse logistics are reduce, substitute, reuse and recycle that are chosen according to the condition in which the material enter the reverse flow. Reverse logistics prioritize source reduction and substitution over reuse and recycling. Source reduction consists on preserving the process while using less resources. Substitution means using more environmentally friendly materials rather than the regular ones which end up as pollutants. Reuse is about employing the same item numerous times in its original form in order to reduce the amount that is discarded. Recycling gives discarded materials a new life by submitting them to chemical or physical processes (Wu and Dunn, 1995; Mourad, 2016).

The actions taken in order to incorporate the three tenants in the supply chain are represented in the recycling entity. Even though the recycling entity is a separate entity, all the other levels of the supply chain should be connected to it. Moreover, when possible various entities should jointly find solutions to become more sustainable. This would mean that the recycling entity would be connected with those entities at the same time. The recycling entity includes all external entities and internal efforts to reuse, reduce and recycle the waste food generated by the company. Figure 3.2 shows the general agri-food framework after incorporating the reverse logistics flows and the recycling entity.

These modifications represent important efforts to create a circular economy inside each company and AFSC since the generation of waste minimized and the SC is designed, not only to benefit the economy, but also the society and the environment. Thus, it enables the use and reuse of raw materials and products to conserve natural resources (Muscio and Sisto, 2020).

There are many possibilities to reduce the resources used in the system, for instance, freight consolidation (fewer trips generated), no packaging, and increasing quality management (fewer defects). Logistics managers should constantly search for more environmentally friendly materials to replace the existing ones throughout the supply chain (Wu and Dunn, 1995).

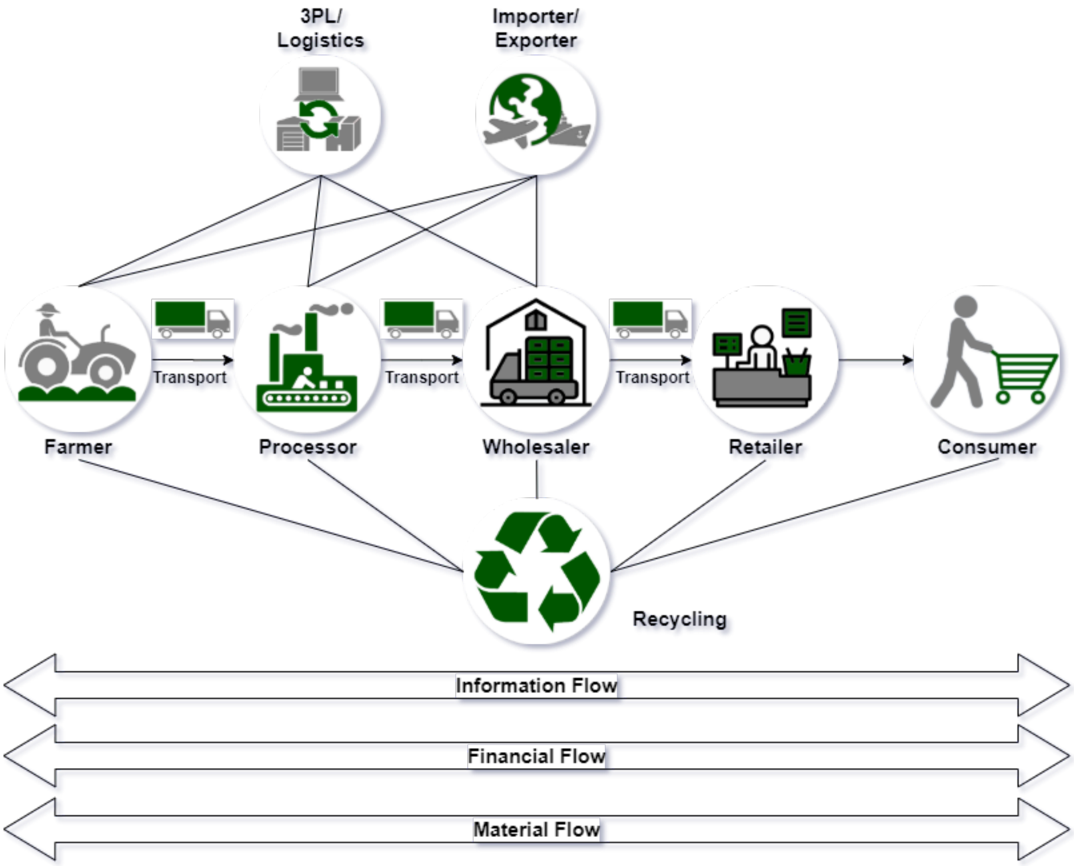


Figure 3.2: Sustainable agri-food supply chain network
(adapted from K.Tsolakisa et al., 2014, Jaffee et al., 2010)

Furthermore, materials can be resold to the supplier if they have the proper conditions for commercialization. The usage of reusable and returnable packaging will increase in the future, which means that the traditional one-way logistics, like the general agri-food framework previously presented (Figure: 3.1), will need to be adapted to handle two-way freight flows (Figure: 3.2). Distribution centers and retail stores need to be able to handle pickups of reusable packaging in addition to drop-offs of normal merchandise. This situation will make the transport network planning more complex with two-way flows and lead times will become longer due to the time spent on pickups. There are also other adjustments, like extra storage space for the returnable containers, modification of information systems and flows to monitor returnables, and training of employees to handle these returnable containers (Wu and Dunn, 1995; Coelho et al., 2020).

When the materials cannot be reused, they can always be recycled. The recycle tenant, needs to deal with a more complex operation since logistics managers need to collect and transport recyclable materials to the handling sites for processing. Then, they can afterwards reenter the supply chain as new resources. And so, recycling requires extra resources for the processing part and the cost may not be justified. On the other hand, this will increase the use of recycled materials in the system (Wu and Dunn, 1995; Coelho et al., 2020).

3.4 A measurement system for an agri-food supply chain

In order to build a tool to measure how sustainable a specific supply chain is, a detailed analyse in what it is important to measure inside each entity and how is needed. Afterwards, some improvements should be implemented to upgrade the sustainable performance of the SC. This is the goal of this section. And so, in the first part will be distinguished the environmental, social and economic dimensions inside the company, as well as operational, the tactical and strategic levels of decision. Then, some hotspots will be identified in each entity and sorted into environmental, social or economic. Next, it will be proposed some key performance indicators to measure those hotspots and some possible improvements that can help minimizing them. It is determined the level of decision that each possible improvement is associated. In the end, these hotspots and indicators will be added to the sustainable agri-food framework presented in the previous section.

3.4.1 The environmental, social and economic indicators

There has been an increased interest in the integration of the economic performance within the environmental and social performance due to the growing desire by stakeholders for more information on a broader range of issues. This will enable the company to compare these indicators across all organizations of the supply chain, and thus useful for mainstream investment analyses. In order to do so, it is important that economic, environmental and social data is transformed into consistent units and presented in a balanced and coherent manner in KPIs (Hřebíček et al., 2013b).

The environmental dimension of sustainability is about the organization's impacts on living and non-living natural systems, for instance ecosystems, land, air, and water. Environmental indicators measure the performance of the supply chain based on the inputs (e.g., material, energy, water) and outputs (e.g., emissions, effluents, waste) that result from the activities of each entity. Furthermore, these indicators also take into account aspects related with biodiversity, environmental compliance, and other relevant information like environmental expenditure and the impacts of products and services (Hřebíček et al., 2013b).

The social dimension of sustainability represents the impact that the organization has on the social systems within which it operates (Hřebíček et al., 2013b). Recently, social sustainability has become of predominant importance in our society due to the need for increased stakeholder awareness regarding, not only the place where the products are made and delivered, but also how they are produced and delivered, which includes in what conditions these activities are done (Jung, 2017a).

The economic dimension of sustainability concerns the organization's influence on the economic state of its stakeholders and on economic systems at local, national, and global levels. The economic indicators measure the flow of capital between the different entities of the supply chain and the most important economic impacts of the organization in the society. Economic performance indicators are used for selection strategies (e.g. maximizing profits, minimizing total costs, company survival) based on direct economic impacts on, for instance, the organization's customers, suppliers, employees, providers of capital, public.

The economic indicators are fundamental to understand not only the financial performance of the organization, but also how sustainable it is. Even though the majority of this information is normally already reported in financial accounts, the organization's contribution to the sustainability of a larger economic system is usually not available and is frequently desired by users (Hřebíček et al., 2013b).

However, indicators should not be studied alone as they do not achieve sustainability on their own. Indicators show important sustainability issues in the food supply chain and so should be analyzed together with other issues (Yakovleva, 2007).

3.4.2 The operational, tactical and strategic decisions

It is very important to understand the operational, tactical and strategic decisions in order to be able to interrelate them. This allows us to understand how to construct realistic plans balanced with each other, which will provide the possibility of having feedback about the adoption of these plans taking into account the real performance of the supply chain processes (Ivanov, 2009).

In this context, taking the case of the AFSC, the transportation mode, the proper routing through the food SC and harvest policies are key factors to ensure that the crops reach the right customer at the right quality, with the appropriate remaining shelf life. Also, because customers are becoming more specialized in their requirements, the final destination of the crops needs also to be considered. For instance, in the case of tomatoes, there are different markets for different types of tomatoes such as mature green and vine ripe tomatoes. Hence, growers need to balance market demands, with their cost and constraints (Ahumada and Villalobos, 2011).

Operational indicators are key to select the best course of managerial actions and secure sustainable decisions Pourhejazy et al. [2020]. Operational decisions are short-term and focus on daily basis activities. While the supply chain is working, problems of operative order planning, supply chain monitoring, and reconfiguration due to operative disruptions (e.g., machine or information systems failures, human errors or cash-flow disruption), as well as tactical/strategic changes (e.g. new products, new order penetration points) are to be dealt with (Ivanov, 2009).

Some of the most important operational activities inside the supply chain are harvesting, scheduling of production activities, storing, packing, and shipping. Within these activities storage and harvesting are particularly important given the limited shelf life of these perishable products. Moreover, since many agricultural activities remain labor intensive, essentially in the primary producers' side, another factor that needs to be considered in the operational planning is the use of labor (Ahumada and Villalobos, 2011). Since the operational decisions deal with short term planning issues, it should incorporate, along with the post-harvest behavior of crops,the effects of weather, transportation time, post-harvest decay, labor and delivery costs (Ahumada and Villalobos, 2011).

One of the differences between **tactical** and operational planning in the agri-food industry is the time frame that these decisions are referring to. When operational decisions are made, growers have better estimates of the crops' yields and of the market conditions than when the tactical plans are prepared. However, even with the reduced uncertainty at the short term, there are still uncontrollable factors influencing the decisions, for instance sudden market fluctuations, the expected yield and maturity of the crops, which are highly dependent on weather conditions, and the post-harvest behavior of the crops (Ahumada and Villalobos, 2011).

Supply chain tactical planning considers a longer time horizon, normally, months or weeks and involves activities like demand forecasting; master production planning; supply planning; replenishment planning; inventory management and transport planning (Ivanov, 2009).

When the tactical decisions are made, the information available can be divided in two groups. The first one incorporates the planting constraints and labor cost and availability. The second group includes the random distribution of crops' prices and crops' yields, as well as transportation, harvesting and distribution costs. Other relevant aspects include demand requirements that must be met, such as preexisting contracts, market demand, and transportation availability during the harvesting period (Ahumada and Villalobos, 2011). According to the entity in question, there are also other information available.

The upper level of the company is responsible for the **strategic** decisions, which are usually related to political and social implications. They deal with more uncertain due to being less data intensive, as there is a smaller amount of information available. Therefore, they are defined in line with the overall goal and vision of the company. These decisions also reflect the rules and regulations of the governing systems (Namany et al., 2019).

Strategic decisions are typically made over a longer time horizon, years and usually considers structural aspects, like supply chain design. Supply chain design deals with issues related with distribution networks and supplier/customer integration. It is a way to achieve competitive advantage and involves supply chain structuring in accordance with the given competitive strategy, supply chain strategy, product program, coordination and distribution strategy, and financial plans (Ivanov, 2009).

Decisions made at the strategic level are normally irreversible and so it is important to analyze the impacts carefully. Moreover, strategic planning can have different goals according to the specific requirements of the supply chain. For example, in many supply chains, logistic is very complex, especially when related with goods distribution. This happens due to the time sensitive aspect of transporting perishable food between the different entities of the supply chain. Another aspect of strategic planning is related to the introduction of new products to the company portfolio (Namany et al., 2019).

3.4.3 Systematization of Key Performance Indicators

After analyzing how the environmental, social and economic indicators are important to control the performance of the company and understating how the operational, tactical and strategic decisions apply to the agri-food industry, a way to measure an AFSC will be figured out in the Tables 3.1 to 3.6. First, it will be identified the main hotspots of the AFSC and then find environmental, social and economic key performance indicators to measure them. In order to give some guidance to the reader, some reference values will be presented. These reference values can also be used by the company to define its targets. Then, it will be suggested possible improvements to minimize or even eliminate the hotspots and identify which SC level of decision (operational, tactical and strategic) they are affecting.

Table 3.1: Primary Producer’s KPIs

PRIMARY PRODUCERS						
Hotspots	Description	KPIs	Reference values	Possible Improvements	SCM Decision Level	References
Environmental						
Soil (S)	Lack of nutrients in the soil (NS)	Soil pH	Soil pH should be between 5.5 and 6.5	Soil nutrient assessment through soil mapping	Operational Level	Omuto and Vargas (2018) Coffee Manufactory (2019) Upadhyay et al. (2003)
	Rapid soil degradation is resulting in a loss of suitable land for crop cultivation and waterway pollution (SD)	% of farms that have adopted 3 or more soil conservation and erosion prevention practices	1.5% (Eastern Washington)	Practicing good agricultural techniques that help replenish and protect the soil	Operational Level	
Water Use (WU)	One of the main inputs of the production process is water	$\frac{(sww - swd) + (gww - gwd) + pw + (seww - sewd) + (tww - twd)}{TP}$ swd – Surface water discharged (m3) sww – Surface water withdrawal (m3) gwd – Ground water discharged (m3) gww – Ground water withdrawal (m3) pw – Produced water (m3) sewd – Seawater discharged (m3) seww – Seawater withdrawal (m3) twd – Third-party water, includes the one sent to other organizations (m3) TP – Total Production (ton)	1214 m^3 / ton (Europe)	Adoption of pressurized on-farm irrigation through pipeline networks	Tactical Level	Aramyan, et al. (2007) FAO (2017) GRI (2015) – EN8 from GSSB Mekonnen, and Hoekstra (2011)
Energy Use (EU)	The amount of energy used during the production process	$\frac{NRF + RF + EC + EG - ES}{TP}$ NRF – Non-renewable fuel consumed (KWh) RF – Renewable fuel consumed (KWh) EC – Electricity, heating, cooling, and steam consumed (KWh) EG – Electricity, heating, cooling, and steam self-generated (KWh)	1237KWh/ha of agricultural area (Portugal)	Use a small portion of the farmed land to install wind turbines, solar panels, and micro-hydro schemes	Strategic Level	Aramyan, et al. (2007) SIMS, R (2015) GRI (2015) – EN3 from GSSB Eurostat (2018)

		ES – Electricity, heating, cooling, and steam sold (KWh) TP – Production (ton)				
Food Lost	Pests measured by flies per trap (FTD)	$\frac{FF}{IT * ND}$ FF – Total number of fruit flies captured IT – Total number of inspected traps ND – Average number of days between inspections	➢ Between 0.1 and 1 means that the population is suppressed ➢ Larger than 1 warrant for continued control efforts	Assessing the quality of the materials used and reviewing the effectiveness these materials and trapping procedures	Tactical Level	FAO (2015) CEC (2019) Bateman et al. (2014)
	Adverse meteorological phenomena (BBL)	$\sum_{m=1}^{M} T_j * R_j$ T - mean temperature on month j (ºC) R - cumulative monthly rainfall on month j (m^3)	➢ Lower than 2500 – Least Risk ➢ Btw 2500 and 5100 – Moderate Risk ➢ Btw 5100 and 10000 – High Risk ➢ Btw 10000 and 12600 – Highest Risk ➢ Higher 12600 – Unsuitable	Institutionalize mechanisms that enable the most vulnerable entities to cope with climate change impacts through collaborative thinking	Strategic Level	Salgueiro, Andrea (2019) FAO (2008) CEC (2019) Smith (2017)
Social						
Food Security (FS)	Disruption of food intake or eating patterns because of lack of money and other resources.	% of the year without access to sufficient food for grower and family	11.1% (USA)	Build a base map of the food system and analyze the available markets near each producer	Tactical Level	Coffee Manufactory (2019) USDA (2009)
		% of farms with access to safe and potable water the entire year	33% (Mundial General Population)	Storage water	Tactical Level	Coffee Manufactory (2019) ODI (2017) UNICEF (2019)
				Build sanitation facilities	Strategic Level	

Labor Practices (LP)	An acceptable wage should allow a worker to afford a decent standard of living for his family, with savings to compensate for catastrophic expenditures.	$\frac{\sum_n W_n}{N}$ W – Wage (€) N – Number of workers	7.2 €/hour (Europe)	Set a budget and find where the money can come from to pay higher wages (for instance, from consumers, brands, or some mix of these)	Strategic Level	Coffee Manufactory (2019) Fair Wear (2019) Hill et al. (2015)
Economic						
Over-production (OP)	Manufacture of products in advance (or in excess of) in comparison with the demand. This wastes money, time, and space	$\frac{PS}{TP}$ PS – Production Sold (ton) TP – Total Production (ton)		Improve farmers' access to information on market overview so they can better align the supply with the demand	Tactical Level	Boedecker, Emily (2019) European Union (2019)
Efficiency (E)	Return on investment (ROI) – Firm's profitability and how effectively the firm uses its capital to generate profit	$\frac{NP}{CI}$ NP – Net Profit (€) CI – Cost of investment (€)	30.2% (Ghana-aquaculture)	Increase sales of co-products and create innovative products using them	Strategic Level	Trigo, Ana (2015) Aramyan, et al. (2007) European Union (2019)
	Production without defects (Prof)	$\frac{QP}{TP}$ QP – Quality Production (ton) TP – Total Production (ton)		Increasing the farmer's experience in the productive process	Tactical Level	
Income (I)	Ensure producers have a sustainable form of income year-round	% employees who live below the poverty line	21.6% (Portugal – general population)	Secure additional avenues of revenue to mitigate potentially low production during harvest seasons	Tactical Level	Coffee Manufactory (2019) European Union (2019) PORDATA (2019)
Actualization Period: Annual						EU, 2015

Table 3.2: Processor's KPIs

PROCESSOR						
Hotspots	Description	KPIs	Reference values	Possible Improvements	SCM Decision Level	References
Environmental						
Material use (MU)	Packaging (P)	Total volume (m^3) or weight (ton) of materials used for packaging	76.7 million tones (all types of food – not only agri-food)	For each material type, identify whether it was purchased from external suppliers or sourced internally, and which activities were used to produce them	Tactical level	Hřebíček et al. (2013) GRI (2015) – EN1 and EN2 from GSSB Marsh, K., and Bugusu, B. (2007)
	Recycled input materials used (RMat)	Percentage of materials recovered for recycling	30.6 million tones (all types of food – not only agri-food)			
Energy Use (EU)	Energy consumption within the organization	$\frac{NRF + RF + EC + EG - ES}{TP}$ NRF – Non-renewable fuel consumed (KWh) RF – Renewable fuel consumed (KWh) EC – Electricity, heating, cooling, and steam consumed (KWh) EG – Electricity, heating, cooling, and steam self-generated (KWh) ES – Electricity, heating, cooling, and steam sold (KWh) TP – Total Production (ton)	Depends a lot on the subsectors within the food processing sector: ➢ Meat – 0.449 KWh/per dollar value of shipments ➢ Milled Grain – 0.647 KWh/per dollar value of shipments ➢ Dairy – 0.564 KWh/per dollar value of shipments ➢ Fats & Oils – 2.11 KWh/per dollar value of shipments (Nebraska)	The environmental footprint of an organization is shaped in part by its choice of energy sources. Changes in the balance of these sources can indicate the organization's efforts to minimize its environmental impacts	Strategic level	Hřebíček et al. (2012) GRI (2015) – EN3 from GSSB
Water Use (WU)	Total volume of water withdrawn by source	$\frac{(sww - swd) + (gww - gwd) + pw + (seww - sewd) + (tww - twd)}{TP}$ swd – Surface water discharged (m3) sww – Surface water withdrawal (m3) gwd – Ground water discharged (m3) gww – Ground water withdrawal (m3) pw – Produced water (m3) sewd – Seawater discharged (m3) seww – Seawater withdrawal (m3)	Water use during the processing strongly depends on the type of product being processed and the equipment used ➢ Influent potato – 4.78 tonnes of water/ton of potato ➢ pigs – 1.5-10m3 /ton of meat ➢ cattle – 2.5-40 m3 /ton of meat ➢ poultry – 6-30 m3 /ton of meat	Report the total volume of water discharges by destination and quality of the water including treatment method	Tactical level	Hřebíček et al. (2012) GRI (2015) – EN8 from GSSB Anantheswaran et al. (2014) Valta et al. (2013)

		twd – Third-party water, includes the one sent to other organizations (m3) TP – Total Production (ton)				
Social						
Supplier selection (SS)	Supplier Assessment for Labor Practices	$\frac{SLP}{NS} * 100$ SLP – New suppliers that were screened using labor practices criteria NS – New suppliers		Report the significant actual and potential negative impacts of labor practices identified inside the company	Tactical level	Hřebíček et al. (2012) GRI (2015) – LA14 from GSSB
Human Rights indicators (HRI)	Security Practices (SP)	$\frac{PT}{P} * 100$ PT – Security personnel who have received formal training in the organization's human rights policies or specific procedures and their application to security P – Employees in the company		Apply measures inside the organization in order to contribute to the elimination of all forms of violation of human rights	Strategic level	Hřebíček et al. (2012) GRI (2015) – HR7 from GSSB
	Significant investment agreements and contracts (IC)	$\frac{HR}{TIC} * 100$ HR – IC that include human rights clauses or that underwent human rights screening TIC – total amount of IC		Determine the significance of the agreement, for instance by the level of approval required within the organization	Strategic level	Hřebíček et al. (2012) GRI (2015) – HR1 from GSSB
Labor/ management relations (LR)	Industrial disputes, strikes and/or lockouts	$\frac{WL}{WT} * 100$ WL – working time lost due to industrial disputes, strikes and/or lockouts (hours) WT – total working time (hours)	11.9% (31/261) (Europe)	Also consider the number of workers at the industrial disputes, strikes and/or lockouts in the equation	Tactical level	Hřebíček et al. (2012) Chernyshev (2003)
Economic						
Price–cost margin (PCM)	Measures performance and competitiveness	$\frac{S + \Delta I - LC - CM}{S + \Delta I}$ S – sales (€) ΔI – Inventory variation (€) LC – labor cost (€) VA – value added (€)	0.121 (Dutch)	Compare firm financial performance between different firms and products	Tactical level	Blažková and Dvouletý (2018) Prince and Thurik et al. (1992)

Efficiency of production (EP)	Measures the efficiency of production and it is influenced by the initiatives taken at the firm level	$\frac{LC}{S}$ LC – labor cost (€) S – sales (€)	17.78 (Czech Republic)	Structural adjustment allowing better educated farmers to enter the sector	Strategic level	Blažková and Dvouletý (2018) OECD (2015)
				The adoption of sustainable practices through new policies	Strategic level	
Indebtedness (Ind)	The ratio of total debt to total equity	$\frac{TL}{SE}$ TL – Total Liabilities (€) SE – Shareholders' Equity (€)	4.36 (Czech Republic)	Send applications to government and nonprofit organizations to receive funds for investments	Strategic level	Blažková and Dvouletý (2018) MOFPI (2017)
Adjusted EBITDA (Adj EBITDA)	Normalizes the company's income and expenses	$EBITDA \pm Adj$ EBITDA – Earnings Before Interest Taxes, Depreciation, and Amortization Adj (Adjustments) – nonrecurring, cash operating elements and company or context-specific elements that bias the view of the financial performance of the business		Take into consideration financial professionals' opinion or their valuation guidelines for best practices to define what are the adjustments to add to this calculation	Strategic level	Naidji (2020)
Adjusted EBITDA margin (AdjM EBITDA)	Allows a more meaningful comparison between companies performance	$\frac{EBITDA}{Rev}$ EBITDA – Earnings Before Interest Taxes, Depreciation, and Amortization Rev – revenues		Consider this KPI for the evaluation of the company's historical operating results and comparison to competitors' operating results	Strategic Level	SEC (2020)
Actualization period: monthly						Torkko et al. (2013)

Table 3.3: Wholesaler’s KPIs

WHOLESALER

Hotspots	Description	KPIs	Reference values	Possible Improvements	SCM Decision Level	References
Environmental						
Energy Use (EU)	Usage of electricity and heat generated by the combustion of fossil fuels to store food	$\frac{NRF + RF + EC + EG - ES}{TP}$ NRF – Non-renewable fuel consumed (KWh) RF – Renewable fuel consumed (KWh) EC – Electricity, heating, cooling, and steam consumed (KWh) EG – Electricity, heating, cooling, and steam self-generated (KWh) ES – Electricity, heating, cooling, and steam sold (KWh) TP – total production (ton)	➢ Btw. 0.0056 and 0.0833 KWh electricity per kg for chilled products ➢ Btw. 0.0556 and 0.1667 KWh electricity per kg for frozen products; (Germany)	Better ventilation by using high efficiency, variable speed fans	Strategic level	FAO (2011) GRI (2015) – EN3 from GSSB Eberle and Fels (2016)
Water Use (WU)	Important indicator to measure the progress towards reducing the amount of resources used	$\frac{(sww - swd) + (gww - gwd) + pw + (seww - sewd) + (tww - twd)}{TP}$ swd – Surface water discharged (m3) sww – Surface water withdrawal (m3) gwd – Ground water discharged (m3) gww – Ground water withdrawal (m3) pw – Produced water (m3) sewd – Seawater discharged (m3) seww – Seawater withdrawal (m3) twd – Third-party water, includes the one sent to other organizations (m3) TP – Total Production (ton)	➢ 1.4 million m3/year (UK) ➢ 1.2 million m3/year (England) ➢ 0.1 million m3/year (Wales) ➢ 0.1 million m3/year (Scotland) ➢ 0.0 million m3/year (Northern Irelnd)	A program for reuse and/or recycling of wastewater and/or gray water	Strategic level	Texas Water Development Board (2013) GRI (2015) – EN8 from GSSB Hasler et al. (2013)
Food Waste and Loss (FWL)	Mass-balance method to infer FWL by measuring inputs and outputs	$ISt + FR - FS - FSt$ ISt – Initial stock (ton)	1723651 tons (retail and wholesale in U.S.)	This formula should also consider changes of food weight during	Tactical level	CEC (2019) BSR (2016)

	alongside changes in levels of stock	FR – Total amount of food received (ton) (e.g., by the processors or imported) FS – Total amount of food sold (ton) (e.g., to the retailers or exported) FSt – Final stock (ton)	77 000 tons (processing and wholesale in Portugal)	processing (e.g., evaporation of water)		
Packaging Wasted (PW)	Impacts upon waste generation caused by packaging material	$\frac{Pck}{Prd}$ Pck – Packaging bought (ton) Prd – Packaging used for the product received (ton)	1.2 Mt (retail and wholesale, U.K.)	Improve packaging material and technology to create a more sustainable package	Strategic level	Yakovleva and Flynn (2004) WRAP (2011)
			Social			
Gender balance (GB)	Percentage of each gender inside the company	$\frac{FW}{TW}$ FW – female workforce (no of employees) TW – total workforce (no of employees)	24.9% (U.S.)	Establish a target for this indicator near 50%	Tactical level	Yakovleva (2007) STATISTICS (2010)
Fair trade (FT)	Fairtrade is one of the few sustainability initiatives addressing fairness in trade	Number of fair-trade initiatives Four components to evaluate the fairness in trade: ➢ Distributive justice (distribution of benefits) ➢ Procedural justice (decision-making processes) ➢ Informational justice (the exchange and use of information) ➢ Inter-personal justice (communication between individuals)		Create series of indictors for each component in order to measure them	Strategic level	Yakovleva and Flynn (2004) Molenaar et al. (2016)
Wages (W)	Average wage given to the employees	$\frac{\sum_n W_n}{N}$ W – Wage (€) N – Number of workers	1099€ (wholesaler and retail trade in general, Portugal)	Compare this indicator with other entities of the supply chain	Strategic level	Yakovleva (2007)
			Economic			

Turnover (T)	Business cycle indicator showing the evolution of the market of goods and services in the industrial sector	The total value of all sales of goods and services (excluding VAT) in €	986,231 € (food, beverages and tobacco)	Distinguish between domestic turnover, which is the turnover generated with sales of units in the same country and non-domestic turnover for sales from a business in one country to someone in another country	Tactical level	Eurostat (2020) Broos et al. (2016)
Gross operating rate (GOR)	Profitability indicator that corresponds to the share of gross operating surplus in turnover	$\frac{GOS}{T}$ GOS – Gross operating surplus (€) T – turnover (€)	0.0370 (36,477/986,231) (food, beverages and tobacco)	Analyze closely the personnel costs	Strategic level	Eurostat (2020) Broos, et al. (2016)
Imported products (ID)	Dependency of the entity where the products are imported	$\frac{IP}{TI}$ IP – Imported Products (ton) TI – Total Input (ton)	6% – Vegetables, fresh, chilled and dried 15% – tropical fruit, fresh or dried, nuts and spices	Create marketing campaigns explaining that buying domestic products is helping domestic workers	Strategic level	Yakovleva and Flynn (2004) European Commission (2019)
Apparent labor productivity (AProd)	Provides an insight about the level of labor intensity required for a given level of financial output	$\frac{GVA}{Wf}$ GVA – Gross value added (€) Wf – Workforce (no of employees)	48€/employee (food, beverages and tobacco)	Use other labor productivity indicator like GDP per hour worked	Tactical level	Yakovleva (2007) Broos et al. (2016) Geneva, International Labor Office (2016)
Actualization Period: Monthly						Ofgem (2020) U.S. CENSUS Bureau (2020)

Table 3.4: Retailer’s KPIs

RETAILER						
Hotspots	Description	KPIs	Reference Values	Possible Improvements	SCM Decision Level	References
Environmental						
Food Not Sold (FNS)	Food that leaves retail stores/ depots because it was not sold	1. Determine the unit to be counted (e.g., individual item, container, bag, truck) 2. If the weight is not already known, weight one or a representative sample of these units (ton) (W) 3. Count the units that left the store because they were not sold (NU) 4. $NU * W$	298 thousand tons (Food Waste and Loss in Portugal)	Supplement with more detailed waste audits at point of disposal	Tactical Level	CEC. (2019) Robertson (2018)
				Understand the causes of food waste (food quality issues/ ‘date expiry’ versus product damage)	Strategic Level	
Ecological brand (EB)	Promote front-runner certified ecological products.	Number of product groups for which a frontrunner ecological product is offered		Stock and encourage consumption of front-runner ecological products	Tactical Level	Schönberger, et al. (2013)
				Develop an own-brand ecological products	Strategic Level	
Energy Use (EU)	The amount of energy consumed on the sales area	$\frac{NRF + RF + EC + EG - ES}{TP}$ NRF – Non-renewable fuel consumed (KWh) RF – Renewable fuel consumed (KWh) EC – Electricity, heating, cooling, and steam consumed (KWh) EG – Electricity, heating, cooling, and steam self-generated (KWh) ES – Electricity, heating, cooling, and steam sold (KWh) TP – total production (ton)	Depend on business practices, store format, product mix, shopping activity and the equipment used for in-store food preparation, preservation, and display. The energy consumption can vary ➢ 700 kWh/m2 sales area in hypermarkets to over ➢ 2000 kWh/m2 sales area in convenience stores (UK)	Recover the waste heat from the refrigeration cycle	Strategic Level	Schönberger, et al. (2013) GRI (2015) - EN3 from GSSB Tassou, et al. (2011) Jerónimo Martins (2019)

Social						
Training and Education (TE)	Organization's investment in maintaining and improving human capital across the entire employee base	Number of employees that have attended any kind of training course	10,538 employees (Jerónimo Martins in Portugal)	Paid educational leave by the organization	Strategic level	GRI (2000-2010) – LA10 from FPSS Jung (2017) Jerónimo Martins (2019)
				Training or education pursued externally and paid for in whole or in part by the organization	Strategic level	
Diversity and Equal Opportunity	Quantitative measure of diversity within an organization, which can be used in conjunction with sectoral or regional benchmarks (OD ➢ OD - Feminine ➢ OD - Under 30 ➢ OD - 30-50)	% of employees in each of the following categories in a company: ○ Gender: Female / Male ○ Age groups: Under 30 years old, 30-50 years old, over 50 years old	➢ 66% – OD (Female)	Use other indicators for which the reporting organization can gather data, for example, citizenship, ancestry and ethnic origin, creed, and disability	Tactical level	GRI (2000-2010) – LA13 from FPSS Jerónimo Martins (2019)
	Identify the total number of employees in each employee category (e.g., board, senior management, middle management, administrative, production, etc.). Categories of employment should be defined based on the reporting organization's own human resources system (GBD ➢ GBD - Feminine ➢ GBD - Under 30 ➢ GBD - 30-50)	% of individuals within the organization's Governance Bodies (e.g., the board of directors, management committee) in each of the following categories: ○ Gender: Female / Male ○ Age groups: Under 30 years old, 30-50 years old, over 50 years old	➢ 67% in management positions – OD (Female) (Jerónimo Martins in Poland, Portugal and Colombia)			

Significant investment agreements and contracts (IC)	Company’s overall commitment to the Human Rights aspects	$\frac{HR}{TIC} * 100$ HR – IC that include human rights clauses or that undergone human rights screening TIC – total amount of IC		Determine the significance of the agreement, for instance by the level of approval required within the organization and then include it in the equation	Strategic level	Hřebíček et al. (2012) GRI (2015) – HR1 from GSSB
Economic						
Gross Margin Return On Selling area (GMROS)	The need to fill the shelves with stock since empty shelves mean “stock out” or “no option”	$\frac{GM}{SF}$ GP – Gross Profit (€) SA – Selling Area (m2)	Between 3.984 and 27.546 taking into account the stores performance on space efficiency	If this data is not available, use other measures instead, like the Gross Margin Return on Inventory (GMROI) and the Gross Margin Return per Full Time Equivalent Labor (GMROL)	Tactical level	Gandhi and Shankar (2014); Anand and Grover (2013) Laskowski and Pettersson (2013)
Information Technology Optimization (ITO)	Level of IT implementation	$\frac{RI}{TR} * 100$ RI – revenue invested in IT (€) TR – total revenue (€)		One important investment is Point of Sales (POS) data usage because it helps in replenishing stock	Strategic level	Anand and Grover (2013)
Food Security (FS)	Sell-Through Rate	$\frac{S}{BOM} * 100$ S – Sales (pieces) BOM – Bill of Materials (stock on hand) (pieces)		There is another indicator that could also be measured: ROCE	Tactical level	Oomen (2014) Anand and Grover (2013)
Actualization Period: Monthly						Eurostat (2020)

Table 3.5 3PL's KPIs

3PL						
Hotspots	Description	KPIs	Reference Values	Possible Improvements	SCM Decision Level	References
Environmental						
Pollutants released (PR)	Sulfur oxides (SOx) and nitrogen oxides (NOx) are the main causes of air pollution, and wastewater	Amount of SOx in the air (ton) Amount of NOx in the air (ton)		Purification and monitoring of pollution of the air caused by volatile organic compounds (VOCs)	Strategic level	Zhang et al. (2007)
Energy Efficiency (EE)	Energy Use (EU)	$\frac{NRF + RF + EC + EG - ES}{TD}$ NRF – Non-renewable fuel consumed (KWh) RF – Renewable fuel consumed (KWh) EC – Electricity, heating, cooling, and steam consumed (KWh) EG – Electricity, heating, cooling, and steam self-generated (KWh) ES – Electricity, heating, cooling, and steam sold (KWh) TD – total distance (ton)	➢ 0.056 kWh/(ton*m^3) – International water-container ➢ 0.083 kWh/(ton*m^3) – Inland water ➢ 0.083 kWh/(ton*m^3) – Rail ➢ 0.75 kWh/(ton*m^3) – Truck ➢ 2.778 kWh/(ton*m^3) – Air (U.S)	Interplay of different components so that more goods fit in the truck and so each one is responsible for less energy	Operational level	Zhang et al. (2007) Wehner (2018) Wakeland et al., 2012
	Vehicle use (VU)	$\frac{VF}{TC} * 100$ VF – Vehicle fill (ton) TC – Total capacity (ton)	➢ Under 50% of available capacity used ○ By weight – 36% ○ By deck area – 27% ➢ Over 90% of available capacity used ○ By weight – 20% ○ By deck area – 37% (U.K.)	Collaboration between entities full truck load	Strategic level	Matopoulos and Bourlakis (2011) Wehner (2018)

Engine performance (EP)	Usage of alternative fuels, like biodiesel	$\frac{AF}{TF} * 100$ AF – Alternative fuels used (litres) TF – Total amount of fuels used (litres)	7.934% (Portugal, transportation of all type of products)	Invest in vehicles that consume biodiesel	Strategic level	Matopoulos and Bourlakis (2011)
Time utilization (TU)	Optimize the routes so that more delivers can be done in each one	Total amount of time used by each truck for each route (hours)		Use advanced computer vehicle routing and scheduling along with systems vehicle telematics	Strategic level	Matopoulos and Bourlakis (2011)
Social						
Training and Education (TE)	Continuous education due to rapidly changing technology and the introduction of new information solutions	Number of employees that have attended any kind of training course	More than 38,000 employees (DHL)	Qualified employment can also be achieved through employment stability, like permanent contracts	Strategic level	Jung (2017) DHL (2019)
Employee average duration of stay (DS)	The turnover rate indicating the loyalty of employees	Number of years an employee remains in the industry		Explain how the employees' work is helping to achieve the organization's goals	Tactical level	Mak and Sockel (2001) Jung (2017)
Unexpected Events (UE)	Loss and Damage frequency (LD)	$\frac{DD + LI}{D} * 100$ DD – Number of damaged items delivered LI – Number of lost items D – Number of deliveries planned		An efficient, up-to-date, integrated computer infrastructure for efficient and accurate tracking of damages	Strategic level	Denizhan amd Konuk (2013) Domingues et al. (2015) DHL (2017) McKinnon et al. (2003)
	Transportation accidents (TA)	Number of accidents occurred during the transportation of products	16 crashes in 24 months (DHL)	A weekly training at a depot on how to report damage cases (e.g. when products fall from forklifts)	Tactical level	

	Cargo theft (CT)	Number of theft events during transportation		Reward system for damage-free operations	Tactical level	
Economic						
Profit per delivery (Prof)	Profit per delivery refers to the benefit produced by each delivery	$\frac{DT - DC}{TD}$ DT – Delivery tariff (€) DC – Delivery cost (€) TD – Number of deliveries		Adjust the delivery cost considering the emissions caused by the transportation and benefit the usage of renewable energies	Strategic level	Domingues et al. (2015) Liu et al. (2019)
Delivery Reliability (DR)	Correct and complete orders delivered on-time (service level)	$\frac{OTD}{TD} * 100$ OTD – On time in full deliveries TD – Number of deliveries	71% (U.K.)	Required development of technological and computerized systems and more professional logistics services	Strategic level	Domingues et al. (2015) McKinnon et al. (2003) Batarlienė and Jarašūnienė (2017)
Performance per each provider (PP)	Customer satisfaction (CS)	$\frac{NC}{TD} * 100$ NC – Number of complaints TD – Number of deliveries	94% (DHL)	Improve the accuracy of all commercial documents to prevent misunderstandings between entities	Strategic level	Dinu (2016)
	Delivery rate within total contracted deliveries (DRt)	$\frac{TD}{CD} * 100$ TD – Number of deliveries CD – Contracted deliveries	99% (DHL)			
Distance empty (DE)	Indicator that measures the distance that a vehicle runs empty	$\sum_m RE$ RE – distance running empty (km) m – number of routes	280,000 kms of 1.45 million kms travelled over 48 hours (U.K.)	Usage of advanced computer vehicle routing and scheduling along with systems vehicle telematics	Strategic level	Dinu (2016) Matopoulos and Bourlakis (2010) McKinnon et al. (2003)
Productivity (Prod)	Number of deliveries per employee	$\frac{OD}{E}$ OD – Number of orders dispatched E – Number of employees		Improve internal motivators by identifying needs of the individual, such as growth, and security	Strategic level	Mak and Sockel, (1999) Domingues et al. (2015)
Actualization Period: daily						Cerasis (2016)

Table 3.6 Recycling's KPIs

Recycling						
Hotspots	Description	KPIs	Reference values	Possible Improvements	SCM Decision Level	References
Environmental						
Emissions (E)	CO2eq emissions (organic) due to food waste throughout the supply chain	$\frac{W_{CO_2eq}}{W_{Food\ Waste}}$ W_{CO_2} – $CO_{2\ eq}$ emissions (ton) $W_{food\ waste}$ – Total amount of FWL (ton)	2.13 t CO2-eq./t food waste	Better forecast the demand knowing that the retailer's prediction and the weather are the main causes of failure	Tactical Level	Rodrigues et al. (2020) Scherhaufer et al. (2018)
Food not sold	Amount of food used for anaerobic digestion compost by the producers (AC)	$\frac{AD}{W_{Food\ Waste}}$ AD – Waste sent to the anaerobic digestion (ton) $W_{food\ waste}$ – Total amount of FWL (ton)	4.18% (lettuce, baby leaves and celery)	Use renewable energy as resource, instead of non-renewable	Strategic Level	Rodrigues et al. (2020) Slorach et al. (2019)
	Amount of food used for compost (CF)	$\frac{Cp}{W_{Food\ Waste}}$ Cp – Waste sent to be composted (ton) $W_{food\ waste}$ – Total amount of FWL (ton)	6.95% (lettuce, baby leaves and celery)	Create standards and rules that allow large scale compost	Strategic Level	Rodrigues et al. (2020) Mourad (2016)
	Amount of food redirected to landfills by the retailers (LF)	$\frac{Ldf}{W_{Food\ Waste}}$ Ldf – Waste sent to the landfills (ton) $W_{food\ waste}$ – Total amount of FWL (ton)	7.38% (lettuce, baby leaves and celery)	Study more appropriate package sizes Create more precise specifications and quality measures	Strategic Level	Rodrigues et al. (2020)
	Amount of waste food that with or without processing is used as pet food (PF)	$\frac{PF}{W_{Food\ Waste}}$ PF – Waste used to produce pet food (ton) $W_{food\ waste}$ – Total amount of FWL (ton)	0.54% (lettuce, baby leaves and celery)	Study more appropriate package sizes Create more precise specifications and quality measures	Strategic Level	Rodrigues et al. (2020)

Social						
Food Banks (FB)	Amount of food donated to foodbanks	$\frac{FDB}{W_{Food\ Waste}}$ FDB – Food donated to foodbanks (ton) $W_{food\ waste}$ – Total amount of FWL (ton)	7.20% (lettuce, baby leaves and celery)	Surplus food needs to be donated early in the supply chain to maximize utility for recipients	Strategic Level	Rodrigues et al. (2020) Alexander and Smaje (2008)
Charity Caused (CC)	Amount of food donated to charity causes	$\frac{ChC}{W_{Food\ Waste}}$ ChC – Food donated for charity causes (ton) $W_{food\ waste}$ – Total amount of FWL (ton)	2.75% (lettuce, baby leaves and celery)	Use the waste generated during and after consumption to produce compost	Strategic Level	Rodrigues et al. (2020) Alexander and Smaje (2008)
Discounted sales (DED)	Discounted sales due to proximity to the expiration dates	$\frac{DS}{W_{Food\ Waste}}$ DS – Discounted sales (ton) $W_{food\ waste}$ – Total amount of FWL (ton)		Shelf life of a product is longer than what is considered. This can result in more selling time and more time for the discounted sells	Tactical Level	Rodrigues et al. (2020) Buisman et al. (2019)
Economic						
Food surplus opportunity cost (SOC)	Can be computed by the marginal price unit costs	$\frac{\Delta P}{\Delta C}$ Δ P – Variation in the production (ton) Δ C – Cost variation due to the increase in the production (€)		When analyzing consider that some products are used to attract consumers and therefore have a low profit margin, but other products are used to gain profit	Strategic Level	Rodrigues et al. (2020) Buisman et al. (2019)
Food surplus loss of sales (SLS)	The increase in sales that would happen in case that amount of food waste and lost was sold	$1 - \frac{TS}{TS + Sf}$ Sf – Sales that could have been done by the food wasted or lost (€) TS – Total amount of sales (€)		More accurate measurement and monitoring of food surplus and externalities Greater supplier-retailer information sharing	Tactical level Strategic Level	Rodrigues et al. (2020)
Supply Chain's Waste (SCW)	Total amount of food wasted throughout the supply chain	$\frac{W_{Food\ Waste}}{TP}$ $W_{food\ waste}$ – Total amount of FWL (ton) TP – Total Production (ton)	33%	Have a better and clearer communication between all entities	Strategic Level	Rodrigues et al. (2020)
Actualization Period: Annual						Surrey Heath Borough Council (2019)

These tables were done by reviewing the existing literature. However, while searching for reference values for the suggested KPIs, there were some challenges encountered. There is not enough legislation to control the impacts of the companies, for instance, there is no upper limit of energy or water consumption. It is also important to increase the number of studies about the impacts of the food industry, not only in the developed countries, but also in developing countries. There are also some KPIs that vary widely according to the product and the country in study. That is why in some reference values there is the country where that value was established or the product for which the value is applied. The fact that the companies do not want to be completely transparent about their targets and impacts made this search harder.

The hotspots identified are the ones that most commonly appear. It does not mean that all of them will apply to any supply chain or that these hotspots are the only ones existing. There are some hotspots that are presented in more than one entity in the supply chain. Hence, the formula used to measure those hotspots is the same so that the comparison of the KPIs is possible and the entity that has the biggest impact identified. This will also allow us to measure the impact of the entire supply chain when all entities involved measure the same KPI.

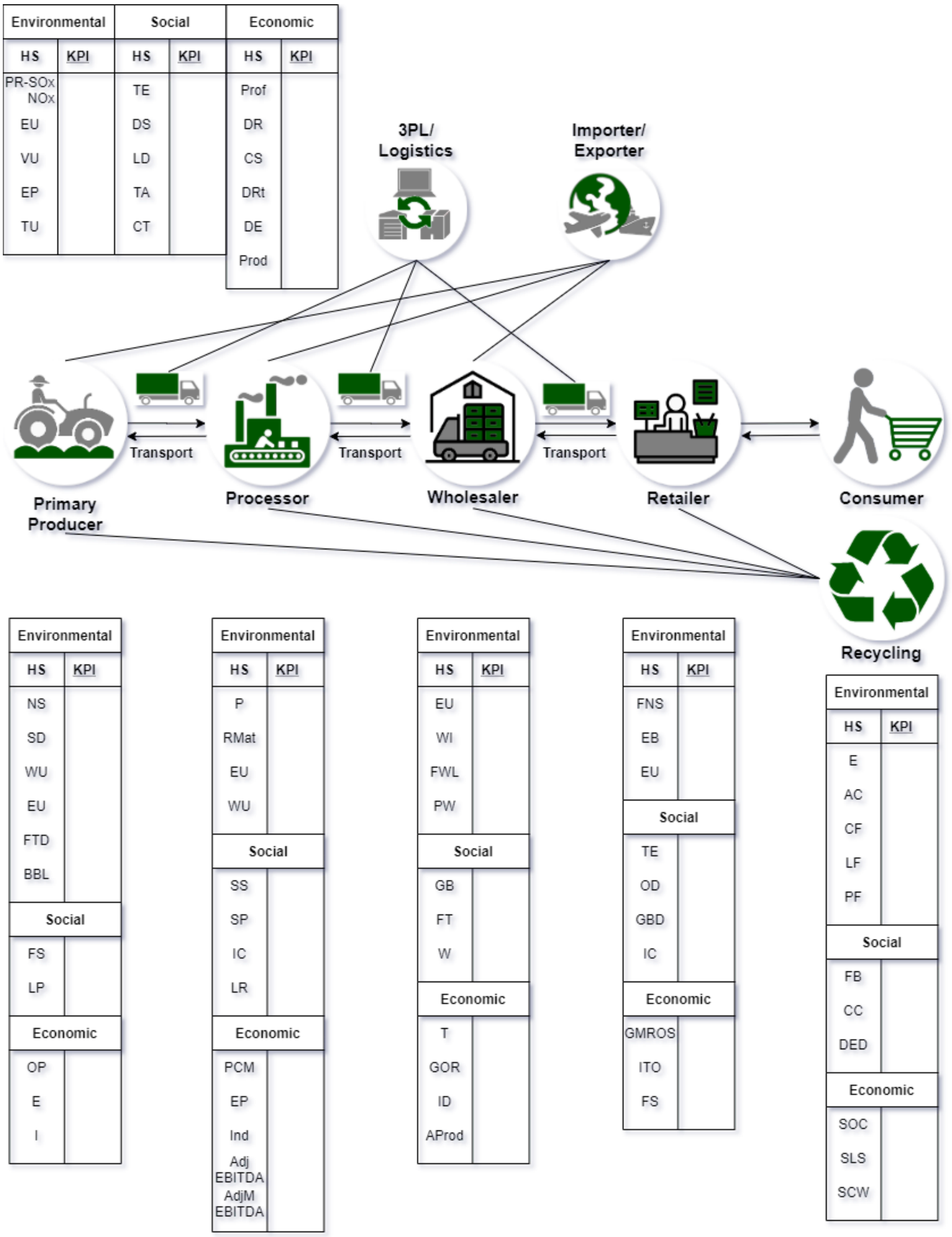
When considering a specific supply chain, it is very important to analyze it in detail so that the possible hotspots are identified. The next step is to find a KPI that translates into a quantitative measure that hotspot, like it was done in the previous tables and then compute its value. In order to understand if those hotspots really exist, the value of the KPI will be compared with other entities of the supply chain or with a competitive company, when it is available. Sometimes, there are some guided table with ranges of values explaining what they mean so that each company can decide which are the values they are targeting.

3.5 Conclusion

In the first part of this chapter a general AFSC was analyzed, identified and described all entities and flows. The key terms that linked AFSC and sustainability were also defined. It is essential that all entities under study have access to those definitions in order to know the exact meaning of each term. This will avoid misunderstandings due to misusage. This way, with all this information, a SAFSC was built and the impact that these changes will have on the environment understood.

Even though theoretically the framework designed is creating an environmentally friendly supply chain, it is very important to make sure that it is being successful and it is not harming the planet. Based on all the information gathered and through literature review, it was identified the most common hotspots and created KPIs to measure them. These KPIs will allow us not only to measure each entity, but also the entire supply chain. Moreover, these hotspots will enable the company managers to control the impact on the environment, as well as the influence on the social and economic dimensions. This way, the company is capable to measure the three pillars of sustainability.

Hence, the SAFSC framework will be joined to the previous tables to create an illustrative image of all entities and their hotspots. This image will not only be a very intuitive way to show the relation between all entities, but also what are the key activities that deserve more attention. Companies can also show all KPIs to their employees so that they can understand what they should improve by comparing themselves to other entities of the supply chain. This will also show them the impact that the company has on the supply chain, as well as on the planet. The Figure 3.3 shows the general sustainable agri-food framework and above each image there is a table with an abbreviation for each hotspot and another column for the KPIs values. In the 3PL entity the table is on the left instead of being above. Information about the customers and export/import was not gather since it is very hard to gather data due to the disparity of consumption pattern.



Environmental		Social		Economic	
HS	KPI	HS	KPI	HS	KPI
PR-SOx NOx		TE		Prof	
EU		DS		DR	
VU		LD		CS	
EP		TA		DRt	
TU		CT		DE	
				Prod	

Environmental	
HS	KPI
NS	
SD	
WU	
EU	
FTD	
BBL	
Social	
FS	
LP	
Economic	
OP	
E	
I	

Environmental	
HS	KPI
P	
RMat	
EU	
WU	
Social	
SS	
SP	
IC	
LR	
Economic	
PCM	
EP	
Ind	
Adj EBITDA	
AdjM EBITDA	

Environmental	
HS	KPI
EU	
WI	
FWL	
PW	
Social	
GB	
FT	
W	
Economic	
T	
GOR	
ID	
AProd	

Environmental	
HS	KPI
FNS	
EB	
EU	
Social	
TE	
OD	
GBD	
IC	
Economic	
GMROS	
ITO	
FS	

Environmental	
HS	KPI
E	
AC	
CF	
LF	
PF	
Social	
FB	
CC	
DED	
Economic	
SOC	
SLS	
SCW	

Figure 3.3: Agri-food supply chain network
(adapted from K.Tsolakisa et al., 2014, Jaffee et al., 2010)

Chapter 4

The Eco-Tool Foundations

In this chapter, a decision supporting tool named Eco-Tool is going to be created, using Microsoft Excel and taking into account all the information gathered in the previous chapters. First, it will be described the goal of the tool and how it is structured. Then the inputs used will be presented, as well as how they are going to be processed in order to achieve the expected outputs. During this explanation, the tool components – excel sheets - will be characterized in order to give a better understanding of the entire tool. Finally, the validation will be performed by applying it to the Greenyard company data. This validation is based on the reports available on the companies' website. After, the results are analyzed and possible supply chain improvements suggested.

4.1 Eco-Tool's aim and assumptions

The aim of the Eco-Tool is to create a collaborative platform that will enable the assessment on how a certain supply chain is sustainable according to the three pillars of sustainability and through a wide range of KPIs. Such tools involve all entities of an AFSC and aims to be easily adaptable to any real SC. The holistic view of the SC assumed can give an understanding about the current state of the SC and support stakeholders decisions. It will also allow each company to analyze how has been progressing over time as the KPIs are measured for the current and previous years. This tool helps the company to understand where its hotspots are located and so gives some guidance to help design the strategic planning to create a more sustainable company. Nevertheless, there are some KPIs that can improve just by changing the tactical and operational plan as it is proposed in the possible improvements in the performance measurement system in chapter 3.

Hence, if there are entities of the SC that do not want to use the Eco-tool, the ones participating can at least access their performance. Thus, the ultimate goal of the Eco-tool is to access in quantitative terms how the company and the SC is performing and progressing considering the three pillars of sustainability and give possible improvements to help companies and SCs be more sustainable. Moreover, this tool allows the performance comparison between different entities in the same level of the supply chain, as well as, between the different levels. This will give an idea of the impact of each level in the overall supply chain impact.

The Eco-tool was created based on a general AFSC framework, see chapter 3, so it does not have any specific company or supply chain into consideration. There are three major assumptions in which this tool is based on:

- Each company is only responsible for one level of the supply chain, which means that a company does not work as a wholesaler and a retailer simultaneously.

- It is possible to have three companies working inside each supply chain level.
- The KPIs chosen for each company measure the most common hotspots of that level of the supply chain.

These assumptions were made so that it is easier for the user to tailor the Eco-Tool to its company. However, they can be changed as it is explained how in the User's guide (Appendix A).

4.2 The tool's structure

As stated, Eco-tool is designed in Microsoft Excel, where the inputs are inserted and the outputs shown. The tool involves a set of tables as characterized in the previous chapter (Tables 3.1 to 3.6), where formulas, KPIs and reference values were defined. Appendix B comprises the table with the inputs of the tool (values that need to be inserted by the user) and the KPIs that are calculated with them.

The first sheet of the Eco-Tool is the *Table of Contents*, as represented in Figure 4.1. Each button created is a link to a different sheet. This *Table of Contents* allows an overall view of the entire supply chain and each entity that composes it.

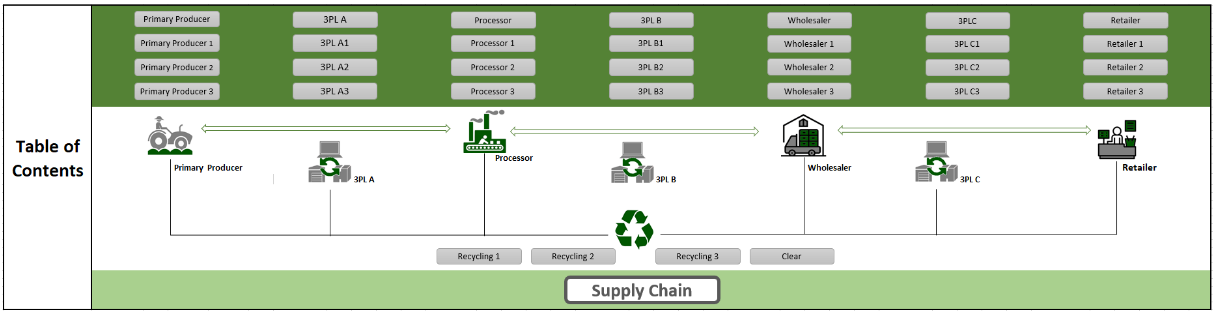


Figure 4.1: Table of Contents sheet

In the Figure above, the sustainable AFSC proposed in chapter 3 can be identified. However, there is a difference, there are three 3PL icons, the 3PLA, the 3PLB and 3PLC. The 3PL A is the one responsible for the connection between the primary producer and the processor, the 3PL B links the processor and the wholesaler and the 3PL C connects the wholesaler and the retailer.

Above each icon are the buttons associated with the level of the supply chain that it represents, except for the recycling icon where the buttons are below. Thus, these buttons are grouped by the level of the supply chain they are affecting and each level has four buttons associated. Every group of buttons is organized in the same way. The first button redirects to the respective *Level of the Supply Chain sheet* and the other three buttons are a link to the three *Entity sheets* that compose that level of the supply chain. Then, the information processed in all these sheets is systematized in the *Supply Chain sheet*.

There are eight levels of the supply chain and each one is composed by four sheets and there is also the supply chain sheet and the table of contents sheet, so in total the ECO-tool is composed by 34 sheets. The way the different sheets connect with each other are explained through Figure 4.2.

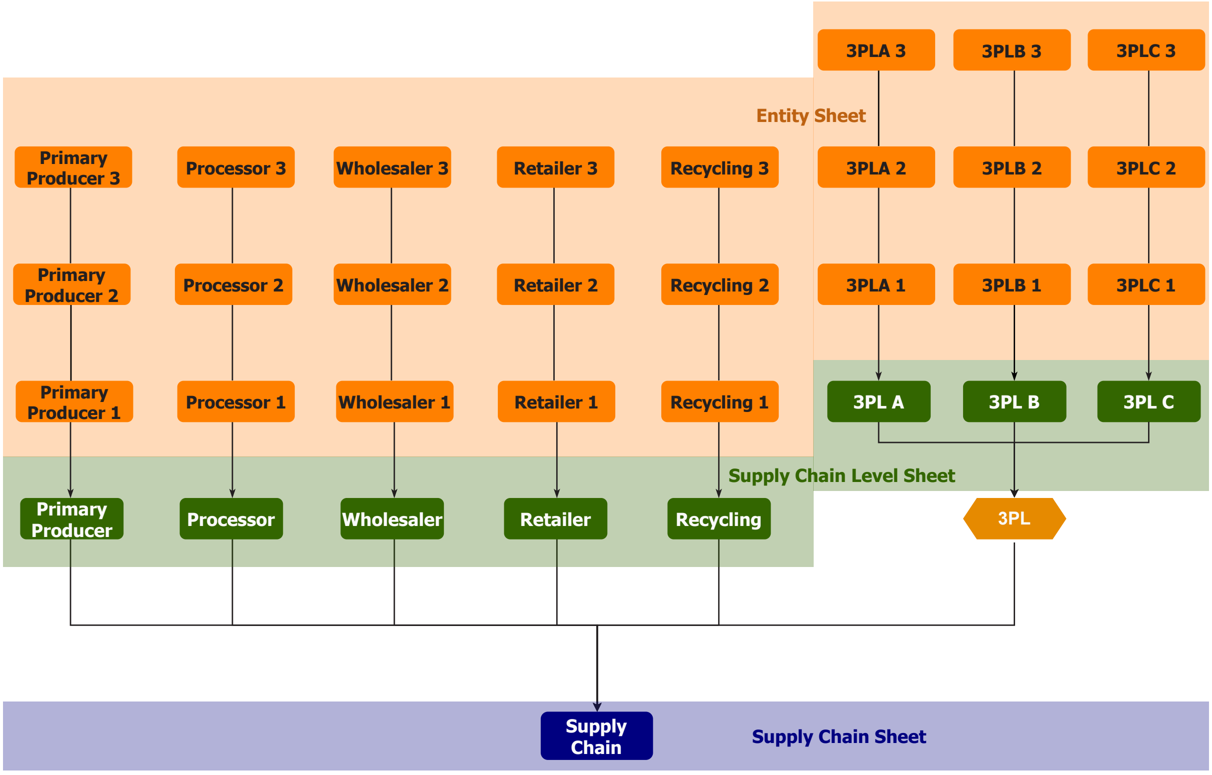


Figure 4.2: Eco-tool structure

In this figure, each sheet is represented by a rectangle. The sheets are connected to each other by arrows and they represent the direction of the flow of information. Also, the sheets are grouped by color according to the data computed there. The orange group is composed by the *Entities sheets*, where the KPIs associated to each company of the SC are computed. The green group includes all *Supply Chain Level sheets* whose goal is to compute the overall performance of each level of the supply chain in terms of sustainability. Then, the *Supply Chain sheet* is the only element of the blue group as it is where all tables with the overall performance of each level of the supply chain are inserted.

There are three entity sheets per each *Supply Chain Level sheet*. Each *Entity sheet* represents a company and in each one the KPIs needed to measure the performance of that company in terms of the three pillars of sustainability. Moreover, in this sheet, the KPIs are systematized in an output table where the company's targets are also added and the evolution over time computed. Then, all output tables are automatically copied to the respective *Supply Chain Level sheet*.

The *Supply Chain Level sheets* have the goal of systematizing the three output tables from the three entities' sheets that compose each level. Based on these tables the overall score table is created with the weighted average of each KPI. In order to do so, a weight needs to be assigned to each entity in the SC according to its importance on the supply chain performance. Each company is responsible to find a way to determine this weight. One way can be, for instance, if it is the processor 1 the one managing the tool, he can assign the weights to each primary producer proportionally to the amount of food received and assign weights to each wholesaler according to the amount of food delivered to each one.

In the *Supply Chain sheet* all the overall score tables of all supply chain levels are systematized in this sheet. Thus, the user can have an overview of the entire supply chain and its KPIs considering the three pillars of sustainability. It is also possible to analyze the performance of each level individually and understand where the critical points are. So, here it can be compared some of the levels or the entire supply chain because if the buttons on the top of the sheet are used, just the KPIs of the entity below them are called, but if the buttons on the left are used the KPIs of all entities are called.

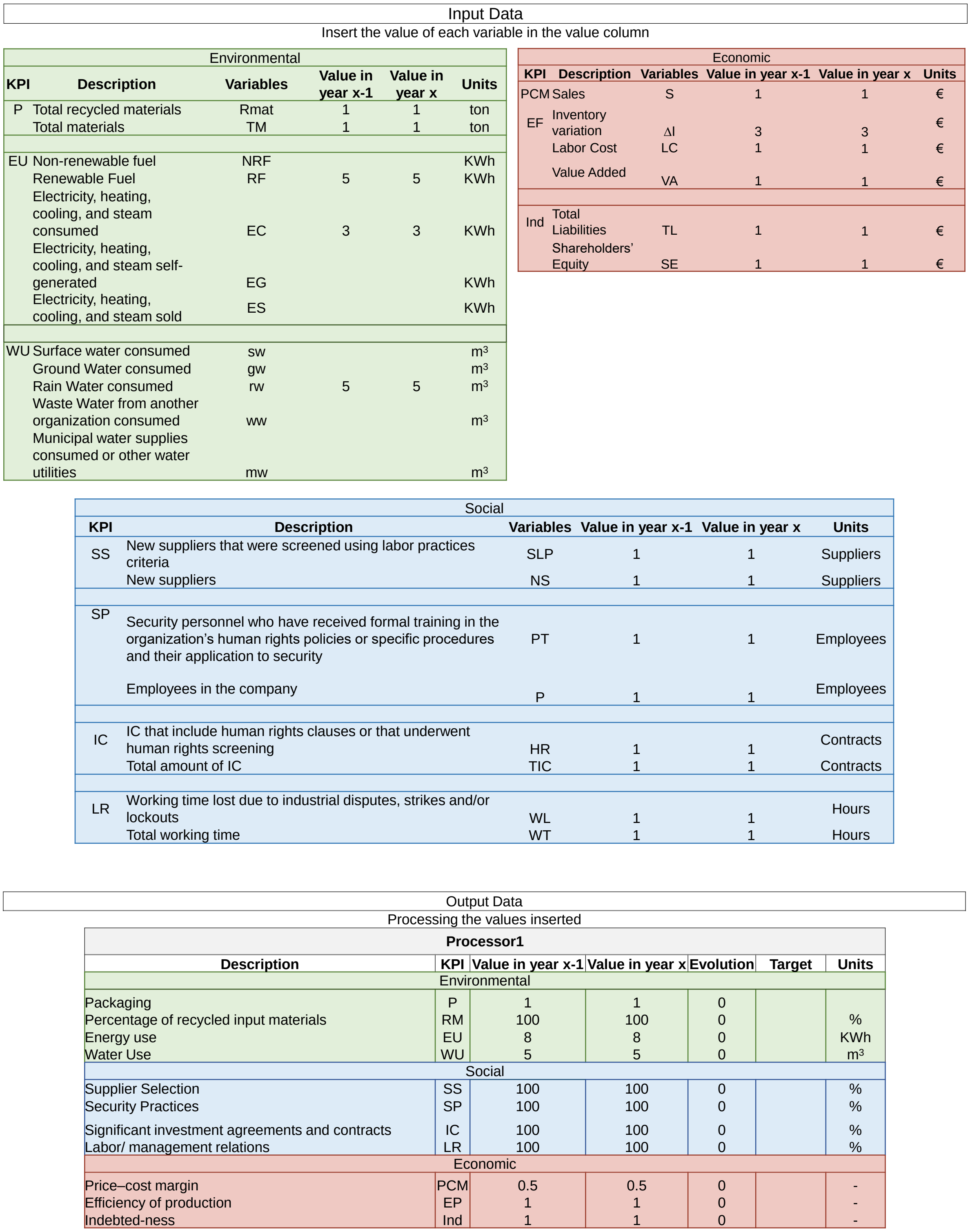
To explain in more detail the Eco-tool, some sheets will be shown. In order to simplify the explanation, the sheets presented will only refer to the processor. However, the supply chain sheets include all levels of the supply chain.

It was considered that there are three companies working as processors in the supply chain, *Processors 1*, *Processors 2* and *Processors 3*. Since there was no data applied yet and the KPIs presented are the same for each level, these three sheets are equal. In Figure 4.3 is represented the *Processor 1 sheet*. The values inserted in the Excel sheet were arbitrary just to make sure the tool was working.

The *Processor 1 sheet*, like all *Entity sheets*, is divided in the input data and the output data areas. The input data is composed by three tables, each with a different color, where the variables' values referring to two consecutive years are inserted. The green one is for the environmental variables' values, the red table for the economic values and the blue table for the social values. Thus, in the first column of these tables are the KPIs' initials that are computed based on the variables. The description column is where the variables are explained and in the variables' column are their initials.

The KPIs are automatically processed and inserted in the table in the output area. The KPIs are sorted according to the sustainability pillar they are measuring and so the table is divided in three groups, each one with the correspondent color (green, red or blue). The description column is referring to the KPIs. The user is also responsible for filling the target column in the output zone, which will make the Evolution column also be filled automatically.

The Eco-Tool is programmed to compute the KPIs presented in the tables created on the previous chapter (Tables 3.1 to 3.6), which are the ones that measure the most common hotspots in the AFSC. However, when this tool is applied to a specific company or supply chain, the user is the one who decides which KPIs to use and he can choose not to use some of the KPIs proposed previously. Therefore, this tool allows the user to change the KPIs according to the data available and add others to measure other hotspots. In this way, the tool can be tailored perfectly to the company needs and specifications.



Input Data

Insert the value of each variable in the value column

Environmental

KPI	Description	Variables	Value in year x-1	Value in year x	Units
P	Total recycled materials	Rmat	1	1	ton
	Total materials	TM	1	1	ton
EU	Non-renewable fuel	NRF			KWh
	Renewable Fuel	RF	5	5	KWh
	Electricity, heating, cooling, and steam consumed	EC	3	3	KWh
	Electricity, heating, cooling, and steam self-generated	EG			KWh
	Electricity, heating, cooling, and steam sold	ES			KWh
WU	Surface water consumed	sw			m^3
	Ground Water consumed	gw			m^3
	Rain Water consumed	rw	5	5	m^3
	Waste Water from another organization consumed	ww			m^3
	Municipal water supplies consumed or other water utilities	mw			m^3

Economic

KPI	Description	Variables	Value in year x-1	Value in year x	Units
PCM	Sales	S	1	1	€
EF	Inventory variation	ΔI	3	3	€
	Labor Cost	LC	1	1	€
	Value Added	VA	1	1	€
Ind	Total Liabilities	TL	1	1	€
	Shareholders' Equity	SE	1	1	€

Social

KPI	Description	Variables	Value in year x-1	Value in year x	Units
SS	New suppliers that were screened using labor practices criteria	SLP	1	1	Suppliers
	New suppliers	NS	1	1	Suppliers
SP	Security personnel who have received formal training in the organization's human rights policies or specific procedures and their application to security	PT	1	1	Employees
	Employees in the company	P	1	1	Employees
IC	IC that include human rights clauses or that underwent human rights screening	HR	1	1	Contracts
	Total amount of IC	TIC	1	1	Contracts
LR	Working time lost due to industrial disputes, strikes and/or lockouts	WL	1	1	Hours
	Total working time	WT	1	1	Hours

Output Data

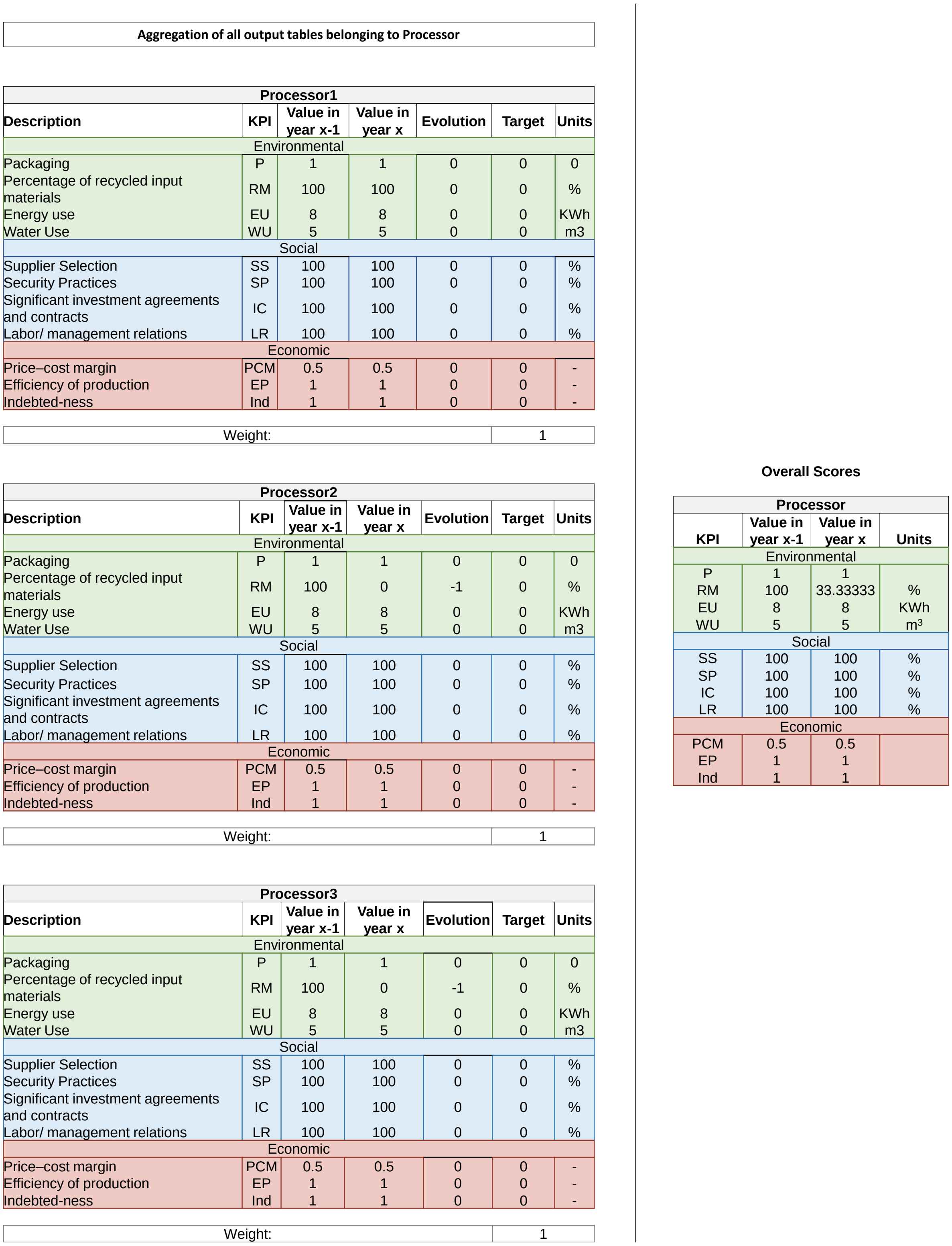
Processing the values inserted

Processor1

Description	KPI	Value in year x-1	Value in year x	Evolution	Target	Units
Environmental						
Packaging	P	1	1	0		
Percentage of recycled input materials	RM	100	100	0		%
Energy use	EU	8	8	0		KWh
Water Use	WU	5	5	0		m^3
Social						
Supplier Selection	SS	100	100	0		%
Security Practices	SP	100	100	0		%
Significant investment agreements and contracts	IC	100	100	0		%
Labor/ management relations	LR	100	100	0		%
Economic						
Price–cost margin	PCM	0.5	0.5	0		-
Efficiency of production	EP	1	1	0		-
Indebted-ness	Ind	1	1	0		-

Figure 4.3: Processor 1 sheet

From each entities sheet, an outcome table is created. Considering the assumptions of this tool, there are three outcome tables referring to each supply chain level. These three tables are the input information of the respective *Supply Chain Level sheet* and are automatically copied to that sheet. Here the overall performance of that supply chain level is measured by computing the weighted average of each KPI. In the Figure 4.4 is represented the *Processors sheet*.



Aggregation of all output tables belonging to Processor

Processor1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Packaging	P	1	1	0	0	0
Percentage of recycled input materials	RM	100	100	0	0	%
Energy use	EU	8	8	0	0	KWh
Water Use	WU	5	5	0	0	m3
Social						
Supplier Selection	SS	100	100	0	0	%
Security Practices	SP	100	100	0	0	%
Significant investment agreements and contracts	IC	100	100	0	0	%
Labor/ management relations	LR	100	100	0	0	%
Economic						
Price–cost margin	PCM	0.5	0.5	0	0	-
Efficiency of production	EP	1	1	0	0	-
Indebted-ness	Ind	1	1	0	0	-

Weight:	1

Processor2						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Packaging	P	1	1	0	0	0
Percentage of recycled input materials	RM	100	0	-1	0	%
Energy use	EU	8	8	0	0	KWh
Water Use	WU	5	5	0	0	m3
Social						
Supplier Selection	SS	100	100	0	0	%
Security Practices	SP	100	100	0	0	%
Significant investment agreements and contracts	IC	100	100	0	0	%
Labor/ management relations	LR	100	100	0	0	%
Economic						
Price–cost margin	PCM	0.5	0.5	0	0	-
Efficiency of production	EP	1	1	0	0	-
Indebted-ness	Ind	1	1	0	0	-

Weight:	1

Processor3						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Packaging	P	1	1	0	0	0
Percentage of recycled input materials	RM	100	0	-1	0	%
Energy use	EU	8	8	0	0	KWh
Water Use	WU	5	5	0	0	m3
Social						
Supplier Selection	SS	100	100	0	0	%
Security Practices	SP	100	100	0	0	%
Significant investment agreements and contracts	IC	100	100	0	0	%
Labor/ management relations	LR	100	100	0	0	%
Economic						
Price–cost margin	PCM	0.5	0.5	0	0	-
Efficiency of production	EP	1	1	0	0	-
Indebted-ness	Ind	1	1	0	0	-

Weight:	1

Overall Scores

Processor			
KPI	**Value in year x-1**	**Value in year x**	**Units**
Environmental			
P	1	1	
RM	100	33.33333	%
EU	8	8	KWh
WU	5	5	m^3
Social			
SS	100	100	%
SP	100	100	%
IC	100	100	%
LR	100	100	%
Economic			
PCM	0.5	0.5	
EP	1	1	
Ind	1	1	

Figure 4.4: Processor sheet

As shown, the three tables in the left are referring to processor 1, processor 2 and processor 3 and were copied from the output table of the respective sheet. Based on the values presented on those tables and the weight associated to those entities, for each KPI an overall score is computed. The overall scores are automatically computed in a different table, which is the output of this sheet.

Therefore, this sheet aims to compute the overall performance of each level of the supply chain.

This sheet gives the user an understanding of the performance of each company and the possibility to compare themselves with the other companies in the same level. Even though it was presented three companies inside each level of the supply chain, there can be any number of companies. However, each company needs to have its own sheet and this sheet needs to be associated to the respective supply chain level sheet.

The last sheet of this tool is the *supply chain*, presented in the Figure 4.5, where the user can have an overview of the entire supply chain and its KPIs considering the three pillars of sustainability. It is also possible to analyze the performance of each level individually and understand where the critical points are. Hence, here it can be compared some of the levels or the entire supply chain because if the buttons on the top of the sheet are used, just the KPIs of the entity below them are called, but if the buttons on the left are used the KPIs of all entities are called. In Appendix C is presented a general code used to program the buttons

When the same company is responsible for more than one level of the supply chain, it can also use this tool. The company has two choices or creates a new sheet with all KPIs associated to those levels or it can internally divide the data and fill the sheets as it was two different segments inside the same company. The first choice is not as good as the second one because the data collected will be associated to numerous and differing tasks and it will prevent the user to know exactly where the hotspot is. For instance, if a company is a wholesaler and a retailer at the same time and the water consumption hotspot is above the target, it is not possible to know which tasks are causing this: the wholesaler's or the retailer's performance. Moreover, the possible improvements cannot be tailored to the needs of the company because they vary widely with the task performed and if there is no information about which supply chain level the hotspot is referring to, there is a wide range of tasks that can be causing that weak spot.

In Appendix D is present the rest of sheets of the Eco-tool that were not presented here, except the case of the entities sheet since is only presented the sheet of the first entity of each level of the supply chain.

4.3 Eco-Tool's validation

In order to illustrate the use and value of the Eco-tool this tool is going to be applied to the Greenyard company. The inputs were gathered by analyzing all reports available in the Greenyard website regarding the years of 2018 and 2019. The outputs generated will be analyzed and some conclusions will be drawn. Moreover, after analyzing the evolution of the company along the years, possible improvements will also be suggested. The Greenyard was the chosen company since it has a wide range of available data, it is a reference company in the field and its main focus is in agricultural products.

It is important to note that in this illustrative example will be applied the Eco-tool to a single company. However, this can also be used to evaluate different companies in one level of the supply chain, as well as, to the entire supply chain. Thus, this illustrative example will give an idea of the outcomes of this tool, without using all the features that are incorporated.

4.3.1 The Greenyard group

Greenyard is a market leader of fresh, frozen and prepared fruit and vegetables, flowers and plants. It is present in 20 different countries and responsible for supplying everyday Europe's leading retailers with a steady and high-quality of fruits and vegetables. The company also provides efficient and sustainable solutions, not only to customers, but also to suppliers by having the best products. Greenyard is known for giving market leading innovation, operational excellence and outstanding service. The company wants to build strong relationships with its customers and uses its expertise at their service to jointly develop a product offer that enhances their business.

The Greenyard's vision is to create healthier lives by helping people enjoy fruit and vegetables at any time, easy, fast and pleasurable, while fostering nature. For the company, its people and key relationships between customers and suppliers are the main assets that enable the Greenyard to achieve its great results. It is one of the largest suppliers of fruit and vegetables in the world. Greenyard is divided in two segments: Fresh and Long Fresh, each a leader in its field. The Long Fresh segments incorporates other two segments: Prepared and Frozen (see Figure 4.5).

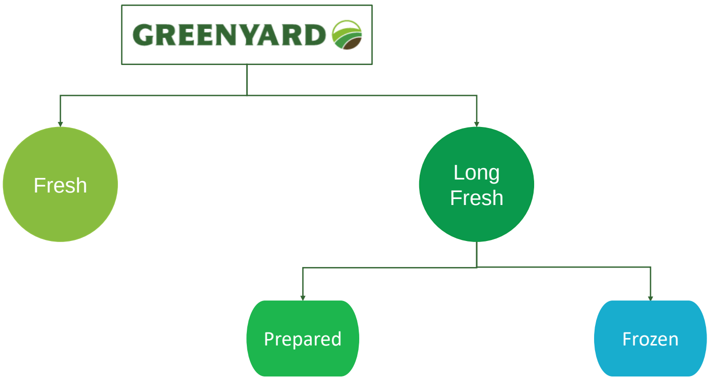


Figure 4.5: Greenyard Segments
(source: Greenyard, 2020a)

These segments work closely with some of the largest food service companies in the world, helping them to expand and widen their offering, develop new markets and successfully anticipate consumer trends (Greenyard, 2020a).

Greenyard Fresh is a global market leader in fresh fruit and vegetables. Its composed by a worldwide network of growers and advanced logistics to deliver any type of fresh produce to customers and consumers at the right moment. Innovation efforts are focused on being more convenience to the consumer and on giving more diversity choices. Greenyard Fresh is also one of Europe's largest fruit ripeners since it has over five hundred dedicated ripening rooms (Greenyard, 2020a). In the Table 4.1

is presented the key figures that describe this segment.

Table 4.1: Greenyard Fresh broad indicators

(adapted from Greenyard, 2020a)

Broad Indicators	
Employees	5500
Distribution center	30
Annual production	1.8 million ton
Growers and suppliers	2500
Customer base - retail	95%
Customer base - food service	5%

The **Greenyard Long Fresh** segment has two divisions, the Greeyard Prepared and the Greenyard Frozen.

Greenyard Prepared processes freshly harvested fruit and vegetables into preserved and prepared food products tailored for the needs of the consumers. The company offers a wide range of preserved fruit and vegetables stored in different ways: in glass, cans, pouches, or foil to give the maximum convenience and easy preparation. Greenyard Prepared has also developed an extended variety of ready-to-eat food products, including sauces, soups, dips, and pasta dishes (Greenyard, 2020a).

Greenyard Frozen is a pioneer and market leader in transforming freshly harvested fruit and vegetables into frozen food products. These products were designed to be easy to store and not time consuming during the preparation step. Its success is very influenced by the state-of-the-art instant freezing technology since it captures the ingredients at the peak of perfection, preserving color, texture, flavor and nutrients, until customer consumption. Packaging was thought for easy portioning because consumers will only serve the quantity they want, and the rest can be saved for later (Greenyard, 2020a). In the Table 4.2, are shown the main KPIs that describe this segment.

Table 4.2: Greenyard Long Fresh broad indicators

(adapted from Greenyard, 2020a)

Broad Indicators		
	Frozen	Prepared
Employees	2000	1000
Countries to export	80	60
Annual production	420,000 ton	280,000 ton
Production sites	13	
Growers	2000	
Land contracted	34,000 ha	
Customer base - retail	67%	
Customer base - food service	22%	
Customer base - food industry	11%	

4.3.2 The Greenyard case study

As it was understood from the Greenyard's description, this company does not represent only one level of the supply chain, since they are responsible for picking up the food from framers, for processing it and store it before delivering it to the retailers. Hence, the company incorporates the roles of the 3PL, the processor and the wholesaler, as it was shown on Figure 4.6. In this context, the data available in the reports concerns the entire company, which means that this data is related to the Greenyard's work as 3PL, processor, wholesaler and recycling. Therefore, the 3PL, processor, wholesaler and recycling KPIs were grouped together in a table. By joining all KPIs, it is assumed that the most common hotspots detected for each level of the supply chain are the hotspots of the entire company. There are common hotspots between the different levels of the supply chain that are measured by the same KPI. When this situation happens, the hotspots in common will not be repeated. The recycling entity was added since it can be applied to any level of the supply chain. As stated before, the data was gathered through the analysis of the sustainability reports of the years 2018 and 2019, as well as, other articles available in the Greenyards website referring to those years (Greenyard, 2019, 2020b,a). However, there were some issues while collecting data to compute the KPIs. On one hand, there was data that was not available, however, on the other hand, there was data that even though was not required was a good substitute to the missing data. Furthermore, there was data that was already processed, which means that there were no calculations needed to achieve the KPIs and so, even though, the variables were not available, the KPIs were. As the tool is able to incorporate other KPIs and change the variables to compute certain KPI, it was possible to incorporate the changes necessary to tailor the tool to the supply chain data.

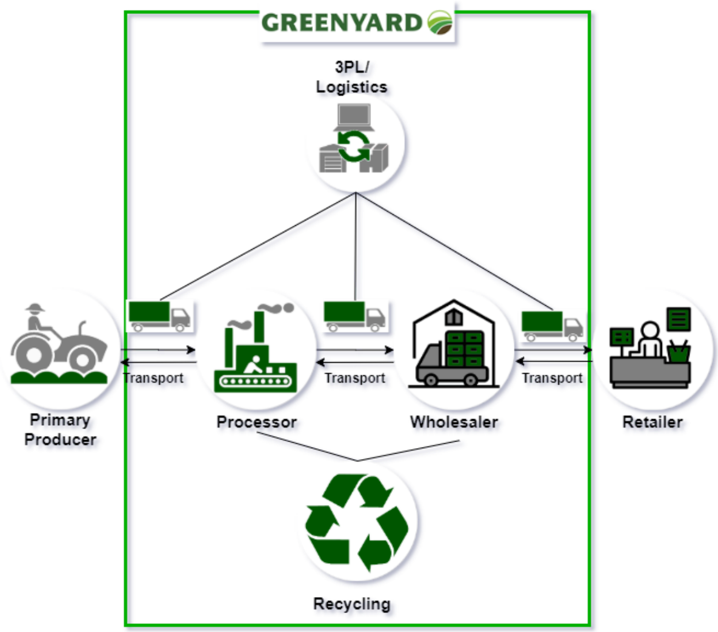


Figure 4.6: Greenyard's levels of the supply chain
(source: Greenyard, 2020a)

4.3.3 Inputs and Outputs

The inputs are displayed in Table 4.3. The values collected account for the years of 2018 and 2019 and also some targets that the company wanted to achieve for the year of 2025 were added.

Table 4.3: Inputs of the Greenyard's tool
(adapted from Greenyard, 2019, 2020b,a)

Input	**Value of 2018**	**Value of 2019**	**Target in 2025**
Environmental			
Percentage of recycled packaging materials	34.9%	35.2%	100%
Energy consumption	680,556 MWh	684,685 MWh	
Water consumption	4,584 million m^3	4,490 million m^3	
Packaging Consumed	79,211 ton	79,645 ton	
Recyclable Packaging	97%	98%	100%
Total fuel consumption	345,916 MWh	346,265 MWh	
Percentage of fuel used for transportation	17.1%	16.9%	
$CO_{2\ eq}$ emissions	-	152,478 ton	Reduce 50%
Total amount of food waste and lost	-	200,000 ton	
Carbon footprint of scope 1 ($CO_{2\ eq}$)	-	74,093 ton	Reduce 50%
Carbon footprint of scope 1 resulted from transportation	-	8%	
Waste sent to the landfills	5%	2%	
Social			
Percentage of suppliers that were screened using a labor practices criteria	-	78%	100%
Percentage of female workers	33%	35%	
Number of fair-trade initiatives	2.8%	3%	
Salary expenses	238,786 €	238,262 €	
Number of employees	9000	8500	
Percentage of production originated from risk countries and regions	24%	24%	
Number of hours of training per employee	11 hours	11 hours	
Number of accidents occurred	340	344	
Food donated for charity and food banks	1636 ton	1648 ton	
Economic			
Adjusted EBITDA	64.5 million €	95.7 million €	
Adjusted EBITDA margin	1.6%	2.4%	
Sales	3.91 million €	4.06 million €	
Turnover	3,912,000 €	4,061,000 €	
Personnel expenses	415,511,000 €	406,372,000 €	
Cost of sales	3.713 million €	3.813 million €	
Operating expenses	4.045 million €	4.062 million €	
Sale of waste	811,000 €	933,000 €	

These targets were not available for all KPIs. Based on the data presented in this table, the key performance indicators for the years of 2018 and 2019 were obtained, see Table 4.4. From this, it is possible to evaluate the performance of the company, as shown in Table 4.4 – column evolution. The information in this column was compared to the values in the ”Target” column to see if the company is developing in the right direction. The data showed in Table 4.4 will be analyzed so as to understand how fairly this data can track the company's performance.

Even though the analyze is referred only to one company, this data comprises all subsidiaries throughout the world. Therefore, between them there are factors that vary, like culture, eating patterns, political issues, traditions and so on. This means that this tool will detect hotspots of the entire company, which do not imply that all subsidiaries have these hotspots or that they do not have some others that appear not to be weak spots of the entire company.

Table 4.4: Output of the Greenyard's tool

Input	**KPI**	**Value of 2018**	**Value of 2019**	**Evolution**	**Target in 2025**	**Units**
Environmental						
Percentage of recycled packaging materials	PP	34.9	35.2	0.0086		%
Recyclable Packaging	P	97	98	0.010	0.0038	%
Energy Use	EU	680,556	684,685	0.006		MWh
Water Use	WU	4,584	4,490	-0.021		10^6 m^3
Fuel consumed for food transportation	FCT	59151.636	58518.785	-0.011		MWh
Emissions	E		0.76239		0.0625	Ton CO_2 eq/ Ton waste
Emissions due to transportation	ET		5927.44			Ton CO_2 eq
Percentage of waste sent to the landfills	LF	5	2	-0.6		%
Social						
Suppliers screened for labor practices	SS	-	78		0.125	%
Gender Balance	GB	33	35	0.061		%
Fair Trade	FT	2.8	3	0.071		%
Wages	W	26.532	28.031	0.057		€/employee
Production in Risk Countries	RC	24	24	0.000		%
Training and Education	TE	11	11	0.000		Hours/ employee
Accidents	A	340	344	0.012		Accidents
Amount of food donated to charity causes	CC	1636	1648	0.007		Ton
Economic						
Adjusted EBITDA	AE	64,500,000	95,700,000	0.484		€
Adjusted EBITDA - margin	AEm	1.6	2.4	0.500		%
Efficiency of production	S	106.23	100.09	-0.058		
Turnover	TE	3,912,000	4,061,000	0.038		€
Personnel Expenses	PE	415,511,000	406,372,000	-0.022		€
Costs of Sales	CS	3,712,509	3,813,320	0.027		€
Operating Expenses	OE	4,044,893	4,062,470	0.004		€
Sale of Waste	SW	811,000	933,000	0.150		€

4.3.4 Interpretation of results

The KPIs computed in the Table 4.4 have the goal of monitoring the most common hotspots of the agri-food industry characterized in chapter 3 to understand how Greenyard is performing in terms of sustainability. In the Table 4.5 it is shown the most common hotspots of the AFSC and the hotspots measured for Greenyard.

Table 4.5: Most common hotspots and Greenyard's hotspots measured

Most common hotspots	Hotspots measured for Greenyard	
Environmental		
Percentage of recycled packaging materials	Percentage of recycled packaging materials	Processor
Recyclable Packaging	Recyclable Packaging	
Energy Use intensity	Energy Use	
Water Use intensity	Water Use	
Food waste and loss		Wholesaler
Packaging wasted		
Engine performance	Fuel consumed for food transportation	3PL
Amount of SOx in the air	Emissions due to transportation	
Amount of NOx in the air		
Vehicle use		
Time utilization		
CO2eq emissions	Emissions	Recycling
Percentage of waste sent to the landfills	Percentage of waste sent to the landfills	
Percentage of waste for anaerobic digestion compost		
Percentage of waste for compost		
Percentage of waste food used as pet food		
Social		
Percentage of suppliers screened for labor practices	Percentage of suppliers screened for labor practices	Processor
Security Practices	Production in Risk Countries	
Significant investment agreements and contracts		
Labor/ management relations		
Gender Balance	Gender Balance	Wholesaler
Fair Trade	Fair Trade	
Wages	Wages	
Training and Education	Training and Education	3PL
Transportation accidents	Accidents	
Employee average duration of stay		
Loss and Damage frequency		
Cargo theft		
Amount of food donated to charity causes	Amount of food donated to charity causes	Recycling
Amount of food donated to foodbanks		
Discounted sales	Discounted sales	
Economic		
Adjusted EBITDA	Adjusted EBITDA	Processor
Adjusted EBITDA - margin	Adjusted EBITDA - margin	
Price–cost margin		
Efficiency of production	Efficiency of production	
Indebtedness		
Turnover	Turnover	Wholesaler
Imported products versus domestic		
Apparent labor productivity	Personnel Expenses	
Gross operating rate	Operating Expenses	
	Costs of Sales	
Profit per delivery		3PL
Delivery Reliability		
Customer satisfaction		
Delivery rate		
Distance empty		
Productivity		
Supply Chain's Waste	Sale of Waste	Recycling
Food surplus loss of sales		
Food surplus opportunity cost		

As demonstrated, some hotspots were not measured since there was not enough data. Therefore, other KPIs were computed to add as much information as possible to the evaluation of the company's performance in terms of sustainability. These KPIs were chosen according to the data available on the Greenyard's reports and the hotspots that were not measured due to lack of information. It is not mandatory that the company has the identified AFSC hotspots, but an analysis of the challenges that the supply chain faces is important. In this context, the company should undergo an internal analysis in order to know its own hotspots and how to measure them.

Although the majority of the KPIs do not have a target defined, in the most part it is known if the company wants to reduce or increase it. When the company is meeting the expectations in the evolution column is represented a green rectangle, when this does do not happen the rectangle is red. However, it is not known if these progressions are significant to have an impact on the efficiency in terms of the three pillars of sustainability since that is what the target is for. There are some rectangles that do not have any contour because, there is not enough information to know if the progression of these KPIs are in line with the strategic objectives of the company. This is the case of production in risk countries, personnel expenses, costs of sales and operating expenses.

The results will be described per pillar of sustainability.

Environmental:

From the results it can be seen that there has been a clear investment by the company in *recyclable packaging* since its target was surpass. Moreover, the more this KPI increase, the better chances are of increasing the percentage and the amount of recycled packaging. Hence, the company could, for instance, reward the costumers who give back their packaging to the retailer and so Greenyard would be the one responsible for recycling it. About the Emission and the Emission due to transportation KPIs, it was not possible to take any conclusions because they were just measured for one year. Anyway, investing in biodiesel and electric vehicles would have a great impact on the environment. According to Viswanathan and Thomai (2020), the synthesis of biodiesel is predominantly based on seed oils and it can be used to reduce the emissions from the engine since the oxygen present in biodiesel promotes clean combustion. Moreover, the increasing usage of electric vehicles will contribute to an improvement of the air quality (Gould and Golob, 1998).

There are some hotspots that are measured with KPIs that on its own are not enough to conclude if the company is having an efficient performance. This is the case of *water and energy consumption* since it's something that varies much with the production size. Greenyard should then measure the water and energy intensity, which is the amount of water and energy per ton of food produced. Furthermore, Greenyard increased the amount of energy used, which did not go as planned, but, as discussed, could have been due to the increase in the production. Does, the company could continue to invest in renewable energy and re-think their processes to make them more efficient.

Even though the values of the total energy and water consumption are available, as well as, the total amount of food produced, these KPIs were not computed because they should be calculated for each segment. This is due to the differences in the usage of this resources caused by the different types of food processing. The same happens with the *fuel consumed* and *emission due to food transportation* since it depends on the distance travelled. Thus, there should be other KPIs that measure the fuel consumed and ton of CO_{2eq} issued per km travelled.

A reduction in the *waste sent to landfills* was also verified, which means that there was more waste recycled, re-used and used for energy recover since these are all the waste's destinations chosen by the Greenyard company. This shows that waste destinations are becoming more environmentally friendly.

Social:

It is not possible to study the progression of the KPI *suppliers screened for labor practices* because there is only one year of data. However, Greenyard should continuously invest in assessing its suppliers for labor practices since its the company's responsibility to choose a supplier that has the same principles. In this perspective, the company's image is also on the line if these assessments do show noncompliance for labor practice.

The amount of *feminine workforce* and *fair-trade volumes* have been increasing as expected. For the last indicator, the company should show to the procurement departments the impact of fair-trade contracts not only for both companies (the supplier and Greenyard), but also for its employees.

Even though, the amount spent in *wages* per employee has been increasing, it does not mean the increment was done in the same proportion throughout the hierarchy. This KPI could be split in two, one referring to the entire company and other referring to the board positions.

It is essential to guarantee the supplier's social compliance, especially in the risk countries. One way could be through monitor the *production that is originated from these countries* is a good indicator of its importance in the overall production and if the number suppliers is changing.

The number of hours of *training* per employee is not increasing and these educational initiatives are a good way to motivate employees, increase their quality and motivation, as well as, a more versatile workforce. This can be one of the reasons that led to the increase of the number of *accidents*. The increase in the number of accidents will have an impact on the number of working hours and can reduce the overall productivity since the other employees can feel unsafe doing the same work.

Even though giving more food to *charity causes* being a good sign, this can be the result of an increase of the amount of food not sold. Therefore, the food sent to charity causes should be measured as a percentage of the food not sold.

Economic:

The *adjusted EBITDA* are earnings before interest, taxes, depreciation, and amortization plus other adjustments to the metric. *Adjusted EBITDA Margin* is the Adjusted EBITDA as a percentage of total revenue. Since both these KPIs are increasing, this means that the company is becoming more profitable. In addition, the *turnover* and the *efficiency of production* have also improved, which means that the company is rising its revenue. Even though, this last KPI is smaller, it is progressing in a positive way since the smaller the KPI is, the more efficient is the production.

The company should monitor the *personnel expenses* since it reflects the strategy of the company associated with the selling and acquire of subsidiaries, the structural growth and the seasonal need's variations. The same happens with the *cost of sales* indicator, which is mainly related with the cost of goods, transport, packaging, warehousing, farming Personnel and temporary workforce. Therefore, every time this KPI is computed, all other costs need to be accessed.

The *operating expenses* include the cost of sales, expenses related to impairment loss, selling, marketing, distribution and administrative. When analyzing this KPI, all the other expenses will also be computed. Even though the money resulted from *selling waste* has increased, it is important to understand why this happened, for instance, due to an increase of waste generated or an increase of its value. This KPI shows that the company was able to recover value from the food that was considered to be waste and not have any value.

4.4 Eco-tool setbacks

The goal of this section is to look over what has been done and what should be executed next in order to have a trustworthy tool and a more solid validation. Even though this tool has a justified theoretical background, presented in Chapter 3, it was not possible to validate it with more than one case study so as to test his feasibility. That is why, this tool should be applied to numerous supply chains, and consequently to various companies. This means that it should be applied to simple supply chains with fewer levels, as well as, to complex supply chains with a wide range of companies and connections between them. Moreover, this tool should be applied during a considerable period of time because it needs to track the companies until they achieve their targets. Furthermore, most of the KPIs are measured annually, and, in order to use all the features of the tool, the data of the last two previous consecutive years should be available. The application of the tool to different case-studies would allow a detail analysis of the data and the identification of improvements that should be implemented.

Moreover, this tool depends highly on the companies involved and how willing they are in sharing information about their internal performance and their connections with other companies. If the communication is not completely transparent and there is no collaboration between the various companies, the tool will not be used to its fully capacity. The goal is than that each company shares its KPIs so that all the companies together can find solutions for the hotspots.

Furthermore, the company also should go through an internal analysis to map the structure of the supply chain and identify the hotspots of each party involved. However, the company can use the most common hotspots gathered in the Chapter 3. This internal analysis has also the goal of understanding which levels of the supply chain each company are responsible for, and how are the connections between the various companies. As a result, this tool cannot be used right away and if this study is flawless, the tool will not work. The KPIs are also not computed automatically, so every time the company wants to know if its performance is improving, someone must do an analyze of the company in order to make sure the tool reflects correctly the supply chain and the companies and then insert the new values and compute the new KPIs.

Regarding the validation tool through the Greenyard company, it was very important to understand how this tool can be tailored to a real case study and how the outputs can be interpreted. However, the data gathered referred to various subsidiaries throughout the world and a wide range of different products and processing facilities (some food is sold fresh, other frozen and other already prepared to be eaten). Each country and each segment of the Greenyard should develop its own study and measure its own KPIs and so considering themselves different entities. In this way, it will be possible to detect exactly where the hotspots are and come up with better improvement suggestions customized for that specific subsidiary and segment.

4.5 Conclusion

In this chapter, the Eco-tool developed was characterized. This appear as a collaborative platform to be used by all entities of an AFSC aiming to achieve a more sustainable supply chain.

In the first part of this chapter, it was explained the aim of the tool, how to evaluate the performance of the supply chain and how the tool may help to increase the transparency along the supply chain to achieve the sustainable goals. Furthermore, the structure of the tool was described and the tool was validated by applying it to the Greenyard company.

This validation was divided in three parts. The first part was about explaining the internal structure of the company and the different segments that compose it. The second one was about gathering the data from Greenyard's reports and inserting it in the Eco-tool. Then this data was processed, which led to the results - output tables. The last part was when the results were explained. Since most of the data was associated to the entire company and not one segment, the KPIs evaluated the company as a whole. This means that it is not possible to understand exactly where the hotspots are, but only which ones exist and how the company is progressing.

Finally, some setbacks of the tool and the validation were explained. In here the main point is that the proposed tool should be applied to a wide range of supply chains and companies, so that more setbacks are identified and corrected.

Chapter 5

Conclusions and Future Work Suggestions

As stated in the Introduction of this work, it is clear that the world is facing very harmful environmental problems. Research has been developed in how to eliminate or minimize the impact of these problems. In this context the aim of this work was to help companies and supply chains becoming more sustainable by creating a tool to measure their sustainability performance. This, among other goals, can help reducing the emissions, food waste and lost, and allow companies keep tracking their hotspots and improve them. After characterizing the problem under study, a literature review on the topic was developed. Then, it was time to describe the basis of the tool and so a more focused analysis of the literature was made in order to create a theoretic background for the tool. Finally, in the last chapter, it was characterized the tool created and explained how to work with it. After, a validation based on the Greenyard reports was done.

The review of the existing literature showed that there was a lack of information for companies who wanted to evaluate their sustainable performance in a quantitative measure and considering an holistic view of the entire supply chain. This way, the tool created in chapter 4 helped filling this gap. This chapter (chapter 2) started by exploring all the key terms related to sustainable agri-food supply chain management. First, the most important aspects linked with sustainability were discussed and it was concluded that sustainability is not only about one single company, but it must take the entire supply chain into consideration. The next topic discussed was how a sustainable agri-food supply chain could be created. In this context, circular economy and life cycle assessment, among other approaches, were considered as efficient strategies. Then, the advantages of mapping supply chains were discussed. Moreover, it was also understood that there is a wide range of possible maps that can be created, so it is necessary to consider the aim and specifications of the different possibilities to choose the most adequate one. Finally, the last section was essential to realize that to achieve a sustainable agri-food supply chain it is mandatory to have a performance measurement system to evaluate it.

The Literature review was essential to make and organize the next chapter, Chapter 3. The analyze of real case studies regarding mapping AFSCs was the base to create the general agri-food supply chain network. Then, the section about sustainable agri-food supply chains was the base to transform the general agri-food supply chain network into a sustainable one. This section, as well as the section about the importance of measuring a food supply chain network gave the highlights needed to gather the most common hotspots present in an AFSC and the KPIs to measure them.

In chapter 3, dedicated to Mapping Agri-food Supply Chains, a general agri-food supply chain was characterized considering all the involved entities, as well as flows and main concepts. It is worth to highlight the role of the MobFood project for the description of the key concepts. These definitions resulted from a brainstorm meeting where important companies in the agri-food sector were involved. The goal is to achieve a deep understanding of this type of supply chains so that it is possible to identify strategies to transform agri-food supply chains into sustainable ones.

It was also clear that to better understand a supply chain there is the need of developing an adequate mapping tool of the sustainable agri-food supply chain to support the identification of the hotspots. After creating a map of the general AFSC network, the next step was to make the necessary changes to transform it into a sustainable one. The main changes were the creation of a reverse flow and adding a recycling entity. This new network was then the basis of the next literature review that had the goal of collecting the most common hotspots in each entity of this supply chain and come up with KPIs to measure them. Then some actions to diminish non-effective and non-efficient activities and procedures (hotspots) were identified. Measuring the KPIs is crucial since their evolution is the reflection of the changes made to create a sustainable and efficient supply chain.

In Chapter 4, the Eco-tool was built to measure the performance of the company or/and the supply chain. This tool can be tailored to any company and any supply chain. That is why, all the VBA code used to program the tool was explained, as well as the structure of the Excel sheets and what is done in each one. This way, all companies of the supply chain can track their progress by computing the KPIs recurrently to make sure that the measures taken to improve the hotspots are having the supposed effects. Still, the company must do an internal study to know which levels of the supply chain is responsible for. Afterwards, part of the tool was validated by analyzing the Greenyard company and measuring the most common hotspots of the supply chain levels that this company is responsible for. To have a better and more precise analysis of the company, data should had been given per country and per segment since the values available were referring to all subsidiaries throughout the world and all segments (the fresh, prepared and frozen segments). This would also allow the formulation of more oriented improvement suggestions and analyze of the results.

The Eco-tool appears as a base tool that provides a new and innovative process to improve the companies' performance taking into account the three pillars of sustainability. This is an original tool that will be added to the already existing research on the field. Moreover, as shown previously, the research and tool created will help reducing the impact of the agri-food sector in the planet. On another perspective, for the companies is also a competitive advantage showing efforts to create more sustainable processes.

5.1 Limitations

There were some limitations felt during the construction of this dissertation. During the literature review, it was noticed a lack of articles about mapping food chains and the agri-food supply chains, especially the sustainable ones. Given this, in chapter 3, a sustainable agri-food supply chain was proposed in order to try to fill this gap. This chapter was also based on previous articles to gather the needed information to build the map. The more focused on the agri-food sector the searched information was, the less data was available. For this reason, there should be more data regarding the description of the information flow that connects the different entities. There was also not enough data about what were the changes that the supply chain needed to do to create a SAFSC.

Moreover, many reference values collected were taken from studies about a wide range or very specific types of foods (not only agri-food) and there was no information at all about others. The case of the reference values taken from the current values of Jerónimo Martins is one example since this company sells a wide variety of products that goes far beyond agri-food products. However, some of these reference values, like energy and water consumption should come from legislation taking into account the impact of these values in the planet and the fact that they depend a lot on the product in hand. So companies should not have referencing numbers, but regulations that they need to follow. Hence, there is a big gap of information in the agri-food industry, essentially regarding methodologies to help businesses become more sustainable. In addition to this, the lack of data creates an obstacle for companies to create their own system to do so.

There are some setbacks that the companies should take into consideration while using this tool. It depends greatly on the data given by the companies and their collaboration, so transparency is a key factor to the success of the outputs. The companies also need to be willing to start measuring some variables that have not been measured before, as well as sharing the KPIs values and their improvements.

Finally, this tool must be more and better tested since only part of the tool was validated. It should be applied to various supply chains and companies. This will allow the companies to share their feedback about the features of the tool and detect improvement actions that can be added. As a result, the Eco-tool would go through a series of adjustments until it is according to the companies and supply chains specifications and needs.

5.2 Future work

In this section some solutions for the limitations detected will be proposed. Starting with chapter 3, it is central to describe different agri-food supply chains, which include the different entities and flows that compose them. This is very important since, for instance, the meat supply chain can be very different from the coffee supply chain, even though they are both agri-food products. For this reason, the systematization of the hotspots should be done to a more specific type of agri-food supply chain, for instance fruits or a specific fruit, instead of any agri-food product.

Regarding the chapter 4, there are also some aspects that could be improved like automatizing more the tool. Before explaining how, it is important to describe what a Natural Language Processing (NLP) is. NLP is a sub-field of Artificial Intelligence that is focused on extraction and manipulation of natural language text or speech for the purpose of creating a map. NLP aims to automatically extract structured information from text, which involves locating and classifying instances (text mentions) of entities and semantic relationships between named entity mentions. Therefore, NLP can help expedite the internal analysis of the company and the supply chain in order to create the supply chain network that is going to be analyzed.

Moreover, a program can be created, for instance with MATLAB, that has as input the data bases of the company without being treated with the goal of processing it and insert the variable values in the Excel. Thus, the output of the MATLAB program is the Excel sheet with these values. In this way, it would not be needed to insert the new values of the variables and the process of gathering the KPIs would be much faster. Through NLP and the MATLAB program it is possible to create a completely automatic tool to measure the performance of the company in terms of sustainability.

It would also be interesting if the tool saved the KPIs over time. This would give the information needed to compute a graphic showing the progression of the company. Furthermore, if these progressions were associated with the improvement actions made by the company, it would be possible to forecast how the company would react to certain changes. This way, the Eco-tool would be able to support even more strategic, tactical and operational decisions.

Finally, testing the tool can be done even if the companies do not want to show their data because the sheets can be locked with a password and only the overall values of each level of the supply chain would be showed. Still, it is very important to test this tool in order to access its feasibility and efficiency. The validation should be done in simple supply chains composed by only a few entities and very complex ones composed by numerous connections between various entities. The same should happen with the companies since this tool needs to be applied to small companies that are responsible for one level of the supply chain and big companies with various segments and representing more than one level of the supply chain. Moreover, it is essential that these validations occur in direct contact with the various companies in order to receive their feedback to understand how intuitive the tool is, if it was helpful and if it met the expectations. This would also give the idea which are the features that the users give more value and, in contrast, the ones that do not bring any value.

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Appendix A

User's Guide

The user need to go through the following steps:

- **Step 1:** Understand which level or levels of the SC is the company responsible for;
    - **Step 1.1:** If the company is responsible for many stages of the food SC and different processing strategies, it is important to split the company into segments and evaluate them individually
- **Step 2:** Determine how the different companies inter relate;
- **Step 3:** Gather the variables that will be measured in the entities' sheet in the Input zone to measure the selected KPIs
    - **Step 3.1:** The KPIs used should be discussed between all companies in the same level of the SC
- **Step 4:** Insert the formula to compute the KPI value in the respective cell of the output zone
- **Step 5:** Fill the data regarding these variables for two years in the entities' sheet or sheets
- **Step 6:** Fill the various entities' sheets of all companies participating in one level of the SC
    - **Step 6.1:** When the size of the table of the KPIs in the output zone is bigger than the one presented in the Eco-tool, change the command that copy that table to the Supply Chain level sheet so that the entire table is copied
    - **Step 6.2:** If there is more than three companies inside the same level of the SC, all of them should have an entity sheet and the output table should be copied to the Supply Chain Level sheet
- **Step 7:** Repeat the step 6 to all Supply Chain Levels
- **Step 8:** Give to each company all the sheets of the Eco-tool
- **Step 9:** Give a weight to each company in each Supply Chain Level sheet
    - **Step 9.1:** When the overall score table in the Supply Chain Level sheet has a different size than the one presented in the Eco-tool, add the command to compute weighted average in the lines that were not filled before
    - **Step 9.2:** This will also imply that the code used to program the buttons in the Supply Chain sheet need to be readjusted since the range of the sells copied changes and consequently the range of cells where the table will be inserted.

This tool can be used for three ends:

- **The first one** is for companies to track the progress and improve its performance. The steps involved are: **step 1**, **step 2**, **step 3**, **step 4** and **step 5**
- **The second one** is when all companies of one SC level want to compare each other performance. The steps involved are: **step 1**, **step 2**, **step 3**, **step 4**, **step 5** and **step 6**
- **The third one** is for each company to have an overview of the SC according to the impact that other companies have on its performance The steps involved are: **step 1**, **step 2**, **step 3**, **step 4**, **step 5**, **step 6**, **step 7**, **step 8** and **step 9**.

Appendix B

Inputs and Outputs of the Eco-tool

In the Table below is shown all the inputs required and KPIs computed with those values.

Table B.1: Inputs and Outputs of the Eco-tool

		Input	**KPI**
PRIMARY PRODUCER	ENVIRONMENTAL	Soil pH	Soil Nutrients
		Farms that have adopted 3 or more soil conservation	Soil Degradation
		Total Farms	
		Surface water consumed	Water Use
		Ground Water consumed	
		Rainwater consumed	
		Wastewater from another organization consumed	
		Municipal water supplies consumed or other water utilities	
		Non-renewable fuel	Energy Use
		Renewable Fuel	
		Electricity, heating, cooling, and steam consumed	
		Electricity, heating, cooling, and steam self-generated	
		Electricity, heating, cooling, and steam sold	
		Fruit Flies captured	Flies per trap
		Inspected Traps	
		Average number of days between inspections	Adverse Meteorology
		Mean Temperature on each month	
		Cumulative Monthly rainfall on month	
	SOCIAL	Farms with access to safe and potable water	Food Security
		Months without access to sufficient food	
		Wage of each worker	Labor Practices
		Number of workers	
	ECONOMIC	Production Sold	Over-production
		Total Production	
		Net Profit	Efficiency
		Cost of Investment	
		Quality Production	
		Employees who live below the poverty line	Income

PROCESSOR	ENVIRONMENTAL	Total recycled materials	Packaging
		Total materials	Percentage of recycled input materials
		Non-renewable fuel	
		Renewable Fuel	
		Electricity, heating, cooling, and steam consumed	Energy use
		Electricity, heating, cooling, and steam self-generated	
		Electricity, heating, cooling, and steam sold	
		Surface water consumed	Water Use
		Ground Water consumed	
		Rainwater consumed	
		Wastewater from another organization consumed	
		Municipal water supplies consumed or other water utilities	
	SOCIAL	New suppliers that were screened using labor practices criteria	Supplier Selection
		New suppliers	
		Security personnel who have received formal training in the organization’s human rights policies or specific procedures and their application to security	Security Practices
		Employees in the company	
		IC that include human rights clauses or that underwent human rights screening	Significant investment agreements and contracts
		Total amount of IC	
		Working time lost due to industrial disputes, strikes and/or lockouts	Labor/ management relations
		Total working time	
	ECONOMIC	Sales	Price–cost margin
		Inventory variation	
		Labor Cost	Efficiency of production
		Value Added	
		Total Liabilities	Indebted-ness
		Shareholders’ Equity	
WHOLESALER	ENVIRONMENTAL	Non-renewable fuel	Energy Use
		Renewable fuel	
		Electricity, heating, cooling, and steam consumed	
		Electricity, heating, cooling, and steam self-generated	
		Electricity, heating, cooling, and steam sold	
		Surface water	Water Use
		Ground water	
		Rainwater stored	
		Wastewater from another organization	
		Municipal water supplies or other water utilities	
		Initial stock	Food Waste and Loss
		Total amount of food received	
		Total amount of food sold	
		Final stock	
		Packaging bought	Packaging Wasted
		Packaging used for the product received	
	SOCIAL	Female Workforce	Gender balance
		Total Workforce	
		Number of fair-trade initiatives	Fair trade
		Wage of each worker	Wages
		Number of workers	

	ECONOMIC	The total value of all sales of goods and services	Turnover
		Gross operating surplus	Gross operating rate
		Imported Products	Imported products versus domestic
		Total Input	
		Gross value added	Apparent labor productivity
		Workforce	
RETAILER	ENVIRONMENTAL	Units that were not sold	Food not sold
		Weight of each unit	
		Number of product groups that have a frontrunner ecological product	Ecological brand
		Non-renewable fuel	Energy use
		Renewable fuel	
		Electricity, heating, cooling, and steam consumed	
		Electricity, heating, cooling, and steam self-generated	
		Electricity, heating, cooling, and steam sold	
	SOCIAL	Number of employees that have attended any kind of training course	Training and Education
		Number of employees	Organization Diversity in terms of gender
		Feminine Employees	
		Employees under 30	Organization diversity in terms of age
		Employees between 30-50	
		Number of employees in the Governance Bodies	Governance Body diversity in terms of gender
		Feminine Employees in the Governance Bodies	
		Employees under 30 in the Governance Bodies	Governance Body diversity in terms of age
		Employees between 30-50 in the Governance Bodies	
		Investment contracts that include human rights clauses or that undergone human rights screening	Significant investment agreements and contracts
		Total amount of investment contracts	
	ECONOMIC	Gross Margin	Gross Margin Return On Floor space
		Square Feet	
		Revenue invested in IT	Information Technology Optimization
		Total Revenue	
		Sales	Food Security
		Bill of Materials	
3PL	ENVIRONMENTAL	Amount of SOx in the air	Pollutants Released
		Amount of NOx in the air	
		Non-renewable fuel	Energy use
		Renewable fuel	
		Electricity, heating, cooling, and steam consumed	
		Electricity, heating, cooling, and steam self-generated	
		Electricity, heating, cooling, and steam sold	
		Vehicle fill	Vehicle use
		Total capacity	
		Alternative fuels	Engine performance
		Total amount of fuels	
		Time used by each truck for each route	Time utilization

	SOCIAL	Number of employees that have attended any kind of training course	Training and Education
		Number of years an employee remains in the industry	Employee average duration of stay
		Number of damaged items delivered	Loss and Damage frequency
		Number of lost items	
		Number of deliveries planned	
		Number of accidents occurred during the transportation	Transportation accidents
		Number of theft events during transportation	Cargo theft
	ECONOMIC	Delivery tariff	Profit per delivery
		Delivery cost	
		Number of deliveries	
		On time in full deliveries	Delivery Reliability
		Number of complaints	Customer satisfaction
		Contracted deliveries	Delivery rate
		Distance that a vehicle runs in each route	Distance empty
		Number of orders dispatched	
		Number of employees	Productivity
RECYCLING	ENVIRONMENTAL	$CO_{2\ eq}$ emissions	Emissions
		Total amount of food waste and loss	
		Total amount of water used	Water Footprint
		Total amount of food waste and loss	
		Waste sent to the anaerobic digestion	Amount of food used for anaerobic digestion
		Waste sent to be composted	Amount of food used for compost
		Waste sent to the landfills	Amount of food redirected to landfills
		Waste used to produce pet food	Amount of waste food used as pet food
	SOCIAL	Food donated to foodbanks	Amount of food donated to foodbanks
		Food donated for charity causes	Amount of food donated to charity causes
		Discounted sales	Discounted sales
	ECONOMIC	Variation in the production	Food surplus opportunity cost
		Cost variation due to the increase in the production	
		Sales that could have been done by the food wasted or lost	Food surplus loss of sales
		Total amount of sales	
		Total Production	Supply Chain’s Waste
Weight of entity of the supply chain			

Appendix C

The code behind the Eco-Tool

To program the buttons presented in the *Supply Chain Sheet* we used the Office Visual Basic for Applications (VBA) in Excel. The code used to program the left buttons is almost the same as the one used for the upper buttons. The first ones are programmed using modules and the others have the code inside them. Each module is responsible for programming the four subs that will afterwards be assigned to the four buttons that each level has and are immediately above it. On the contrast, each of the left button is responsible for one of the sustainable pillars of all levels of the supply chain of for cleaning everything. Even though the code is basically the same, the line-up is very different.

Since the code does not vary too much a broad one was created in order to the reader understand what was done in the VBA code and to create his own code.

The first part of the code Figure C.1 involves the definition of all variables. This is performed throughout this sub. Even though, there was no direct action resulting from this part of the code, understanding each variable is very important to understand what we will explain next.

```
    Sub EnvPP()
    Dim i As Integer
    Dim z As Integer
    Dim x As Integer
    Dim Posi As String
    Dim Pst As String
    Dim shRead As Worksheet, shWrite As Worksheet
```

Figure C.1: Variable's declaration

After defining the variables it is referred an Excel sheet to two of those variables in the Figure C.2. The first line has the purpose of assigning to the variable ShRead the sheet of the Level (””Level sheet”) we want to copy the table. The second line is assigning to the variable ShWrite the sheet where the entire supply chain is and also where the table will be pasted (”Supply Chain Sheet”). The third line has the goal of copying the table that is between ”range of cells” where the table is located.

```
Set shRead = ThisWorkbook.Worksheets("Level sheet")
Set shWrite = ThisWorkbook.Worksheets("Supply Chain Sheet")
shRead.Range("range of cells").Copy
```

Figure C.2: Reference Variables

The aim of the Figure C.3 is to find if the KPIs of the sustainable pillar that were copied in the previous code were already written in the table and if so happened then the KPIs copied will be written on top of the existing KPIs. If that did not happen, we do not go inside the cycle for. The cycle has the goal of going through all lines (between the first line and last line) of the column number where the entire table with all KPIs is, in the Supply chain sheet. This cycle is looking for one of the ”Sustainable Pillars” and if it finds it, the program will paste the copied table and the comments.

```
x = 0
For i = First line To Last line
    Posi = Cells(i, Column number).Value
    If Posi = "Sustainable Pillar" Then
        shWrite.Range ("Column Letter" & i).PasteSpecial xlPasteValues
        shWrite.Range("Column Letter" & i).PasteSpecial xlPasteComments
        x = 1
    End If
Next i
```

Figure C.3: The KPIs already written

If the code skipped the cycle for, then it will go to the Figure C.4, inside the if and paste the copied table in the column (”Column Letter”). In order to do so, the program will search for the first blank space where there is also nothing in line after.

```
If x = 0 Then
    shWrite.Range("Column
       Letter" & Rows.Count).End(xlUp).Offset(1).PasteSpecial xlPasteValues
End If
```

Figure C.4: First time writing the KPIs

The goal of the Figure C.5 is to paste also the comments of the table written by the previous code. That is why this if will only be true when the previous if is also true (the condition is the same). The logic behind this cycle for is the same one used for the first cycle for.

```
If x = 0 Then
    For z = First line To Last line
    Pst = Cells(z, Column number).Value
    If Pst = "Sustainable Pillar" Then
        On Error Resume Next
        shWrite.Range("Column Letter" & z).PasteSpecial xlPasteComments
    End If
    Next z
End If
End Sub
```

Figure C.5: Writing the comments

The Figure C.6 has the goal of clear all the contents of the cells presented in the range of cells, as well as the comments associated with these cells.

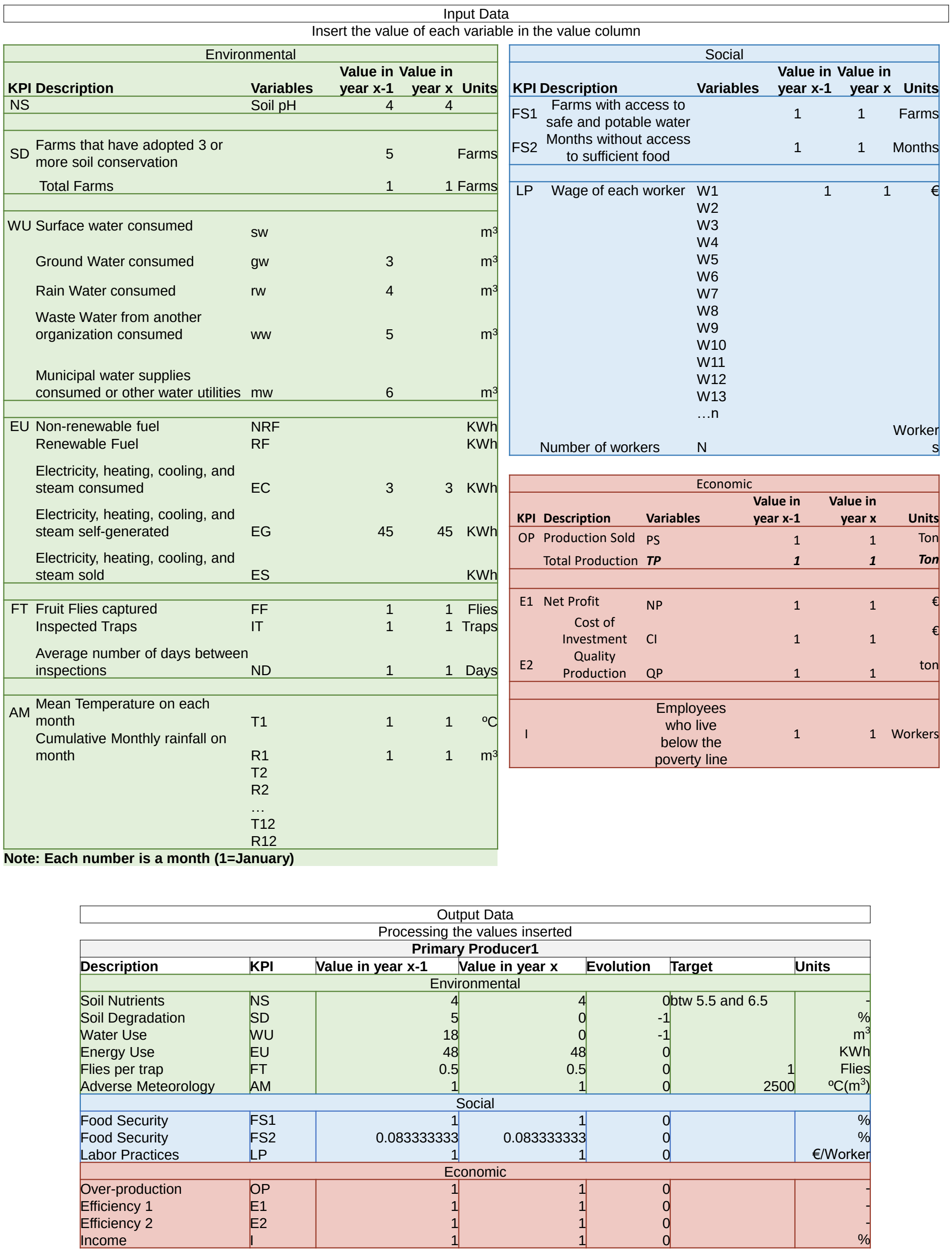
```
Sub ClearPP()
Range("range of cells").ClearContents
Range("range of cells").ClearComments
End Sub
```

Figure C.6: Clear the contents

Appendix D

Excel sheets

In this section will be shown the page of the first entity of each level of the supply chain sheet and the sheet of each supply chain level.



Input Data

Insert the value of each variable in the value column

Environmental

KPI	Description	Variables	Value in year x-1	Value in year x	Units
NS		Soil pH	4	4	
SD	Farms that have adopted 3 or more soil conservation		5		Farms
	Total Farms		1	1	Farms
WU	Surface water consumed	sw			m^3
	Ground Water consumed	gw	3		m^3
	Rain Water consumed	rw	4		m^3
	Waste Water from another organization consumed	ww	5		m^3
	Municipal water supplies consumed or other water utilities	mw	6		m^3
EU	Non-renewable fuel	NRF			KWh
	Renewable Fuel	RF			KWh
	Electricity, heating, cooling, and steam consumed	EC	3	3	KWh
	Electricity, heating, cooling, and steam self-generated	EG	45	45	KWh
	Electricity, heating, cooling, and steam sold	ES			KWh
FT	Fruit Flies captured	FF	1	1	Flies
	Inspected Traps	IT	1	1	Traps
	Average number of days between inspections	ND	1	1	Days
AM	Mean Temperature on each month	T1	1	1	ºC
	Cumulative Monthly rainfall on month	R1	1	1	m^3
		T2			
		R2			
		…			
		T12			
		R12			

Note: Each number is a month (1=January)

Social

KPI	Description	Variables	Value in year x-1	Value in year x	Units
FS1	Farms with access to safe and potable water		1	1	Farms
FS2	Months without access to sufficient food		1	1	Months
LP	Wage of each worker	W1	1	1	€
		W2			
		W3			
		W4			
		W5			
		W6			
		W7			
		W8			
		W9			
		W10			
		W11			
		W12			
		W13			
		…n			
	Number of workers	N			Workers

Economic

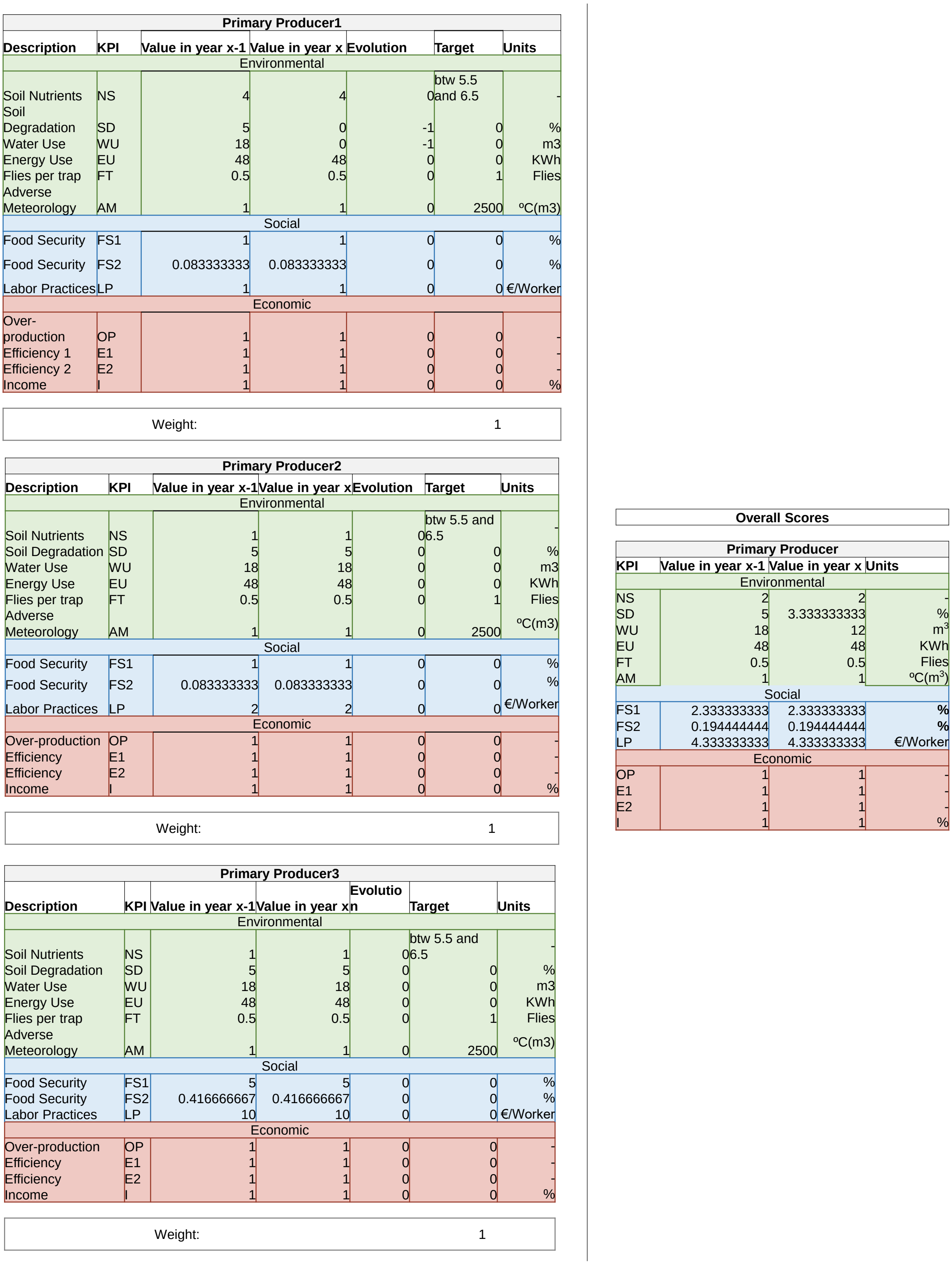
KPI	Description	Variables	Value in year x-1	Value in year x	Units
OP	Production Sold	PS	1	1	Ton
	Total Production	***TP***	***1***	***1***	***Ton***
E1	Net Profit	NP	1	1	€
	Cost of Investment	CI	1	1	€
E2	Quality Production	QP	1	1	ton
I		Employees who live below the poverty line	1	1	Workers

Output Data

Processing the values inserted

Description	KPI	Value in year x-1	Value in year x	Evolution	Target	Units
Primary Producer1						
Environmental						
Soil Nutrients	NS	4	4	0	btw 5.5 and 6.5	-
Soil Degradation	SD	5	0	-1		%
Water Use	WU	18	0	-1		m^3
Energy Use	EU	48	48	0		KWh
Flies per trap	FT	0.5	0.5	0	1	Flies
Adverse Meteorology	AM	1	1	0	2500	ºC(m^3)
Social						
Food Security	FS1	1	1	0		%
Food Security	FS2	0.083333333	0.083333333	0		%
Labor Practices	LP	1	1	0		€/Worker
Economic						
Over-production	OP	1	1	0		-
Efficiency 1	E1	1	1	0		-
Efficiency 2	E2	1	1	0		-
Income	I	1	1	0		%

Figure D.1: Primary Producer 1 sheet



Primary Producer1

Description	KPI	Value in year x-1	Value in year x	Evolution	Target	Units
Environmental						
Soil Nutrients	NS	4	4	0	btw 5.5 and 6.5	-
Soil Degradation	SD	5	0	-1	0	%
Water Use	WU	18	0	-1	0	m3
Energy Use	EU	48	48	0	0	KWh
Flies per trap	FT	0.5	0.5	0	1	Flies
Adverse Meteorology	AM	1	1	0	2500	ºC(m3)
Social						
Food Security	FS1	1	1	0	0	%
Food Security	FS2	0.083333333	0.083333333	0	0	%
Labor Practices	LP	1	1	0	0	€/Worker
Economic						
Over-production	OP	1	1	0	0	-
Efficiency 1	E1	1	1	0	0	-
Efficiency 2	E2	1	1	0	0	-
Income	I	1	1	0	0	%

Weight: 1

Primary Producer2

Description	KPI	Value in year x-1	Value in year x	Evolution	Target	Units
Environmental						
Soil Nutrients	NS	1	1	0	btw 5.5 and 6.5	-
Soil Degradation	SD	5	5	0	0	%
Water Use	WU	18	18	0	0	m3
Energy Use	EU	48	48	0	0	KWh
Flies per trap	FT	0.5	0.5	0	1	Flies
Adverse Meteorology	AM	1	1	0	2500	ºC(m3)
Social						
Food Security	FS1	1	1	0	0	%
Food Security	FS2	0.083333333	0.083333333	0	0	%
Labor Practices	LP	2	2	0	0	€/Worker
Economic						
Over-production	OP	1	1	0	0	-
Efficiency	E1	1	1	0	0	-
Efficiency	E2	1	1	0	0	-
Income	I	1	1	0	0	%

Weight: 1

Primary Producer3

Description	KPI	Value in year x-1	Value in year x	Evolution	Target	Units
Environmental						
Soil Nutrients	NS	1	1	0	btw 5.5 and 6.5	-
Soil Degradation	SD	5	5	0	0	%
Water Use	WU	18	18	0	0	m3
Energy Use	EU	48	48	0	0	KWh
Flies per trap	FT	0.5	0.5	0	1	Flies
Adverse Meteorology	AM	1	1	0	2500	ºC(m3)
Social						
Food Security	FS1	5	5	0	0	%
Food Security	FS2	0.416666667	0.416666667	0	0	%
Labor Practices	LP	10	10	0	0	€/Worker
Economic						
Over-production	OP	1	1	0	0	-
Efficiency	E1	1	1	0	0	-
Efficiency	E2	1	1	0	0	-
Income	I	1	1	0	0	%

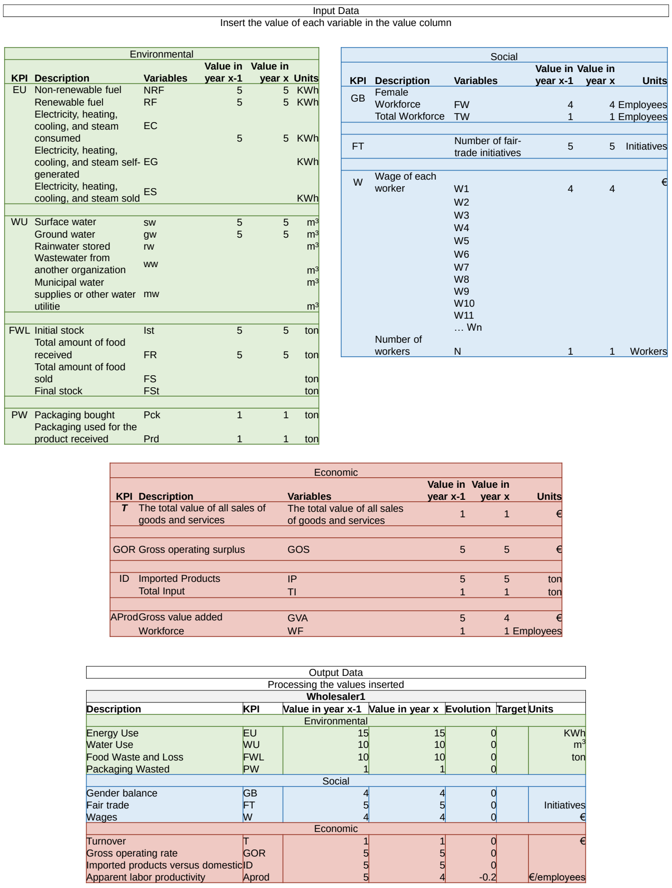
Weight: 1

Overall Scores

Primary Producer

KPI	Value in year x-1	Value in year x	Units
Environmental			
NS	2	2	-
SD	5	3.333333333	%
WU	18	12	m^3
EU	48	48	KWh
FT	0.5	0.5	Flies
AM	1	1	ºC(m^3)
Social			
FS1	2.333333333	2.333333333	**%**
FS2	0.194444444	0.194444444	**%**
LP	4.333333333	4.333333333	€/Worker
Economic			
OP	1	1	-
E1	1	1	-
E2	1	1	-
I	1	1	%

Figure D.2: Primary Producer sheet



Input Data

Insert the value of each variable in the value column

Environmental					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
EU	Non-renewable fuel	NRF	5	5	KWh
	Renewable fuel	RF	5	5	KWh
	Electricity, heating, cooling, and steam consumed	EC	5	5	KWh
	Electricity, heating, cooling, and steam self-generated	EG			KWh
	Electricity, heating, cooling, and steam sold	ES			KWh
WU	Surface water	sw	5	5	m^3
	Ground water	gw	5	5	m^3
	Rainwater stored	rw			m^3
	Wastewater from another organization	ww			m^3
	Municipal water supplies or other water utilitie	mw			m^3 m^3
FWL	Initial stock	Ist	5	5	ton
	Total amount of food received	FR	5	5	ton
	Total amount of food sold	FS			ton
	Final stock	FSt			ton
PW	Packaging bought	Pck	1	1	ton
	Packaging used for the product received	Prd	1	1	ton

Social					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
GB	Female Workforce	FW	4	4	Employees
	Total Workforce	TW	1	1	Employees
FT		Number of fair-trade initiatives	5	5	Initiatives
W	Wage of each worker	W1	4	4	€
		W2			
		W3			
		W4			
		W5			
		W6			
		W7			
		W8			
		W9			
		W10			
		W11			
		… Wn			
	Number of workers	N	1	1	Workers

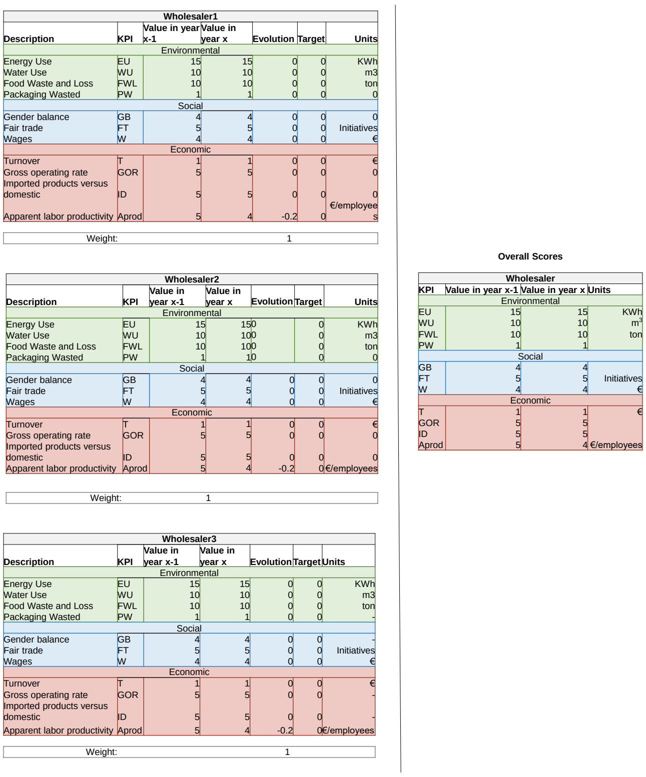
Economic					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
T	The total value of all sales of goods and services	The total value of all sales of goods and services	1	1	€
GOR	Gross operating surplus	GOS	5	5	€
ID	Imported Products	IP	5	5	ton
	Total Input	TI	1	1	ton
AProd	Gross value added	GVA	5	4	€
	Workforce	WF	1	1	Employees

Output Data

Processing the values inserted

Wholesaler1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Energy Use	EU	15	15	0		KWh
Water Use	WU	10	10	0		m^3
Food Waste and Loss	FWL	10	10	0		ton
Packaging Wasted	PW	1	1	0		
Social						
Gender balance	GB	4	4	0		
Fair trade	FT	5	5	0		Initiatives
Wages	W	4	4	0		€
Economic						
Turnover	T	1	1	0		€
Gross operating rate	GOR	5	5	0		
Imported products versus domestic	ID	5	5	0		
Apparent labor productivity	Aprod	5	4	-0.2		€/employees

Figure D.3: Wholesaler 1 sheet



Wholesaler1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Energy Use	EU	15	15	0	0	KWh
Water Use	WU	10	10	0	0	m3
Food Waste and Loss	FWL	10	10	0	0	ton
Packaging Wasted	PW	1	1	0	0	0
Social						
Gender balance	GB	4	4	0	0	0
Fair trade	FT	5	5	0	0	Initiatives
Wages	W	4	4	0	0	€
Economic						
Turnover	T	1	1	0	0	€
Gross operating rate	GOR	5	5	0	0	0
Imported products versus domestic	ID	5	5	0	0	0
Apparent labor productivity	Aprod	5	4	-0.2	0	€/employees

Weight:	1

Wholesaler2						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Energy Use	EU	15	15	0	0	KWh
Water Use	WU	10	10	0	0	m3
Food Waste and Loss	FWL	10	10	0	0	ton
Packaging Wasted	PW	1	1	0	0	0
Social						
Gender balance	GB	4	4	0	0	0
Fair trade	FT	5	5	0	0	Initiatives
Wages	W	4	4	0	0	€
Economic						
Turnover	T	1	1	0	0	€
Gross operating rate	GOR	5	5	0	0	0
Imported products versus domestic	ID	5	5	0	0	0
Apparent labor productivity	Aprod	5	4	-0.2	0	€/employees

Weight:	1

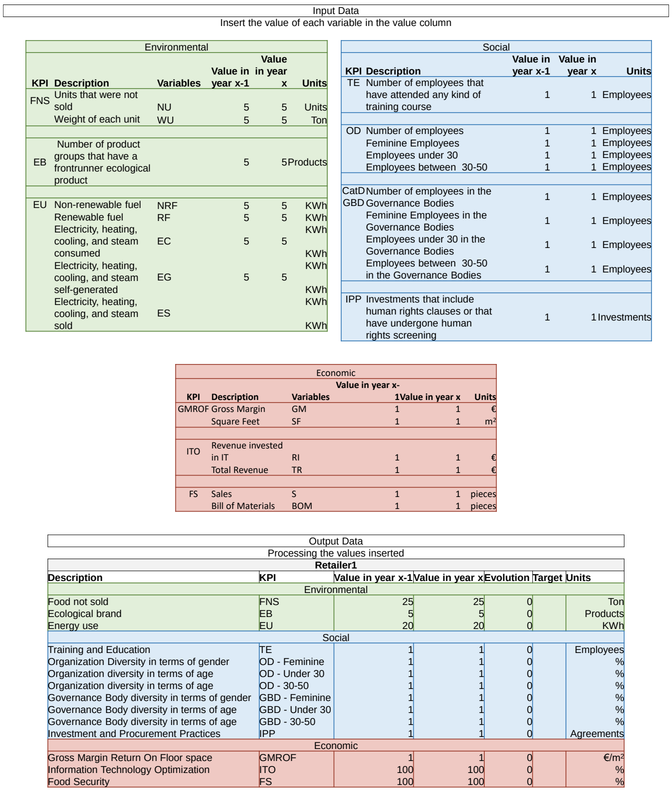
Wholesaler3						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Energy Use	EU	15	15	0	0	KWh
Water Use	WU	10	10	0	0	m3
Food Waste and Loss	FWL	10	10	0	0	ton
Packaging Wasted	PW	1	1	0	0	-
Social						
Gender balance	GB	4	4	0	0	-
Fair trade	FT	5	5	0	0	Initiatives
Wages	W	4	4	0	0	€
Economic						
Turnover	T	1	1	0	0	€
Gross operating rate	GOR	5	5	0	0	-
Imported products versus domestic	ID	5	5	0	0	-
Apparent labor productivity	Aprod	5	4	-0.2	0	€/employees

Weight:	1

Overall Scores

Wholesaler			
KPI	**Value in year x-1**	**Value in year x**	**Units**
Environmental			
EU	15	15	KWh
WU	10	10	m^3
FWL	10	10	ton
PW	1	1	
Social			
GB	4	4	
FT	5	5	Initiatives
W	4	4	€
Economic			
T	1	1	€
GOR	5	5	
ID	5	5	
Aprod	5	4	€/employees

Figure D.4: Wholesaler sheet



Input Data

Insert the value of each variable in the value column

Environmental					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
FNS	Units that were not sold	NU	5	5	Units
	Weight of each unit	WU	5	5	Ton
EB	Number of product groups that have a frontrunner ecological product		5	5	Products
EU	Non-renewable fuel	NRF	5	5	KWh
	Renewable fuel	RF	5	5	KWh
	Electricity, heating, cooling, and steam consumed	EC	5	5	KWh KWh
	Electricity, heating, cooling, and steam self-generated	EG	5	5	KWh KWh
	Electricity, heating, cooling, and steam sold	ES			KWh KWh

Social				
KPI	**Description**	**Value in year x-1**	**Value in year x**	**Units**
TE	Number of employees that have attended any kind of training course	1	1	Employees
OD	Number of employees	1	1	Employees
	Feminine Employees	1	1	Employees
	Employees under 30	1	1	Employees
	Employees between 30-50	1	1	Employees
CatD GBD	Number of employees in the Governance Bodies	1	1	Employees
	Feminine Employees in the Governance Bodies	1	1	Employees
	Employees under 30 in the Governance Bodies	1	1	Employees
	Employees between 30-50 in the Governance Bodies	1	1	Employees
IPP	Investments that include human rights clauses or that have undergone human rights screening	1	1	Investments

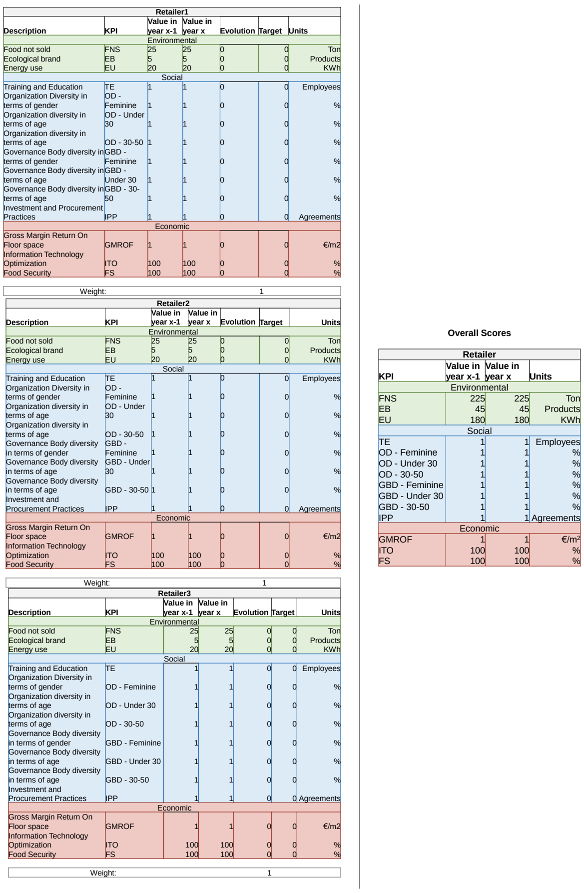
Economic					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
GMROF	Gross Margin	GM	1	1	€
	Square Feet	SF	1	1	m²
ITO	Revenue invested in IT	RI	1	1	€
	Total Revenue	TR	1	1	€
FS	Sales	S	1	1	pieces
	Bill of Materials	BOM	1	1	pieces

Output Data

Processing the values inserted

Retailer1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Food not sold	FNS	25	25	0		Ton
Ecological brand	EB	5	5	0		Products
Energy use	EU	20	20	0		KWh
Social						
Training and Education	TE	1	1	0		Employees
Organization Diversity in terms of gender	OD - Feminine	1	1	0		%
Organization diversity in terms of age	OD - Under 30	1	1	0		%
Organization diversity in terms of age	OD - 30-50	1	1	0		%
Governance Body diversity in terms of gender	GBD - Feminine	1	1	0		%
Governance Body diversity in terms of age	GBD - Under 30	1	1	0		%
Governance Body diversity in terms of age	GBD - 30-50	1	1	0		%
Investment and Procurement Practices	IPP	1	1	0		Agreements
Economic						
Gross Margin Return On Floor space	GMROF	1	1	0		€/m²
Information Technology Optimization	ITO	100	100	0		%
Food Security	FS	100	100	0		%

Figure D.5: Retailer 1 sheet



Retailer1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Food not sold	FNS	25	25	0	0	Ton
Ecological brand	EB	5	5	0	0	Products
Energy use	EU	20	20	0	0	KWh
Social						
Training and Education	TE	1	1	0	0	Employees
Organization Diversity in terms of gender	OD - Feminine	1	1	0	0	%
Organization diversity in terms of age	OD - Under 30	1	1	0	0	%
Organization diversity in terms of age	OD - 30-50	1	1	0	0	%
Governance Body diversity in terms of gender	GBD - Feminine	1	1	0	0	%
Governance Body diversity in terms of age	GBD - Under 30	1	1	0	0	%
Governance Body diversity in terms of age	GBD - 30-50	1	1	0	0	%
Investment and Procurement Practices	IPP	1	1	0	0	Agreements
Economic						
Gross Margin Return On Floor space	GMROF	1	1	0	0	€/m2
Information Technology Optimization	ITO	100	100	0	0	%
Food Security	FS	100	100	0	0	%

Weight: 1

Retailer2						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Food not sold	FNS	25	25	0	0	Ton
Ecological brand	EB	5	5	0	0	Products
Energy use	EU	20	20	0	0	KWh
Social						
Training and Education	TE	1	1	0	0	Employees
Organization Diversity in terms of gender	OD - Feminine	1	1	0	0	%
Organization diversity in terms of age	OD - Under 30	1	1	0	0	%
Organization diversity in terms of age	OD - 30-50	1	1	0	0	%
Governance Body diversity in terms of gender	GBD - Feminine	1	1	0	0	%
Governance Body diversity in terms of age	GBD - Under 30	1	1	0	0	%
Governance Body diversity in terms of age	GBD - 30-50	1	1	0	0	%
Investment and Procurement Practices	IPP	1	1	0	0	Agreements
Economic						
Gross Margin Return On Floor space	GMROF	1	1	0	0	€/m2
Information Technology Optimization	ITO	100	100	0	0	%
Food Security	FS	100	100	0	0	%

Weight: 1

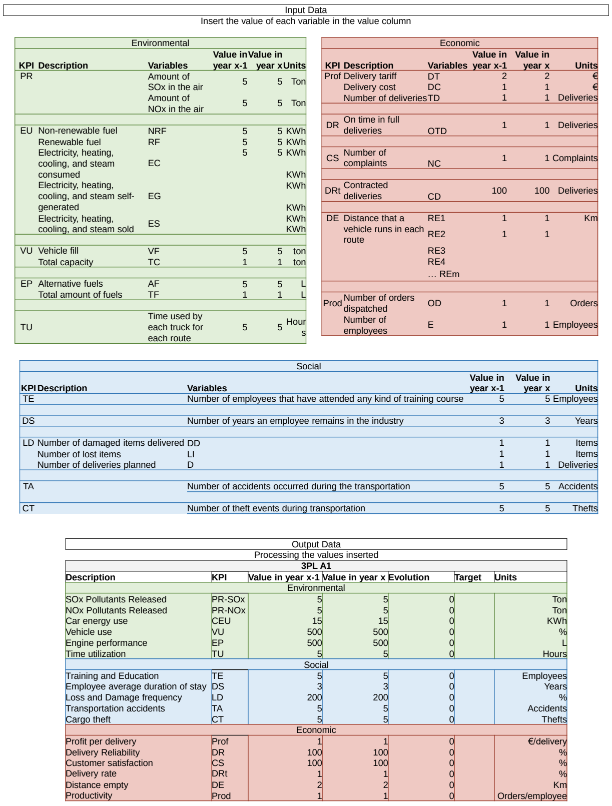
Retailer3						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Food not sold	FNS	25	25	0	0	Ton
Ecological brand	EB	5	5	0	0	Products
Energy use	EU	20	20	0	0	KWh
Social						
Training and Education	TE	1	1	0	0	Employees
Organization Diversity in terms of gender	OD - Feminine	1	1	0	0	%
Organization diversity in terms of age	OD - Under 30	1	1	0	0	%
Organization diversity in terms of age	OD - 30-50	1	1	0	0	%
Governance Body diversity in terms of gender	GBD - Feminine	1	1	0	0	%
Governance Body diversity in terms of age	GBD - Under 30	1	1	0	0	%
Governance Body diversity in terms of age	GBD - 30-50	1	1	0	0	%
Investment and Procurement Practices	IPP	1	1	0	0	Agreements
Economic						
Gross Margin Return On Floor space	GMROF	1	1	0	0	€/m2
Information Technology Optimization	ITO	100	100	0	0	%
Food Security	FS	100	100	0	0	%

Weight: 1

Overall Scores

Retailer			
KPI	**Value in year x-1**	**Value in year x**	**Units**
Environmental			
FNS	225	225	Ton
EB	45	45	Products
EU	180	180	KWh
Social			
TE	1	1	Employees
OD - Feminine	1	1	%
OD - Under 30	1	1	%
OD - 30-50	1	1	%
GBD - Feminine	1	1	%
GBD - Under 30	1	1	%
GBD - 30-50	1	1	%
IPP	1	1	Agreements
Economic			
GMROF	1	1	€/m²
ITO	100	100	%
FS	100	100	%

Figure D.6: Retailer 1 sheet



Input Data

Insert the value of each variable in the value column

Environmental					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
PR		Amount of SOx in the air	5	5	Ton
		Amount of NOx in the air	5	5	Ton
EU	Non-renewable fuel	NRF	5	5	KWh
	Renewable fuel	RF	5	5	KWh
	Electricity, heating, cooling, and steam consumed	EC	5	5	KWh KWh
	Electricity, heating, cooling, and steam self-generated	EG			KWh KWh
	Electricity, heating, cooling, and steam sold	ES			KWh KWh
VU	Vehicle fill	VF	5	5	ton
	Total capacity	TC	1	1	ton
EP	Alternative fuels	AF	5	5	L
	Total amount of fuels	TF	1	1	L
TU		Time used by each truck for each route	5	5	Hours

Economic					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
Prof	Delivery tariff	DT	2	2	€
	Delivery cost	DC	1	1	€
	Number of deliveries	TD	1	1	Deliveries
DR	On time in full deliveries	OTD	1	1	Deliveries
CS	Number of complaints	NC	1	1	Complaints
DRt	Contracted deliveries	CD	100	100	Deliveries
DE	Distance that a vehicle runs in each route	RE1	1	1	Km
		RE2	1	1	
		RE3			
		RE4			
		… REm			
Prod	Number of orders dispatched	OD	1	1	Orders
	Number of employees	E	1	1	Employees

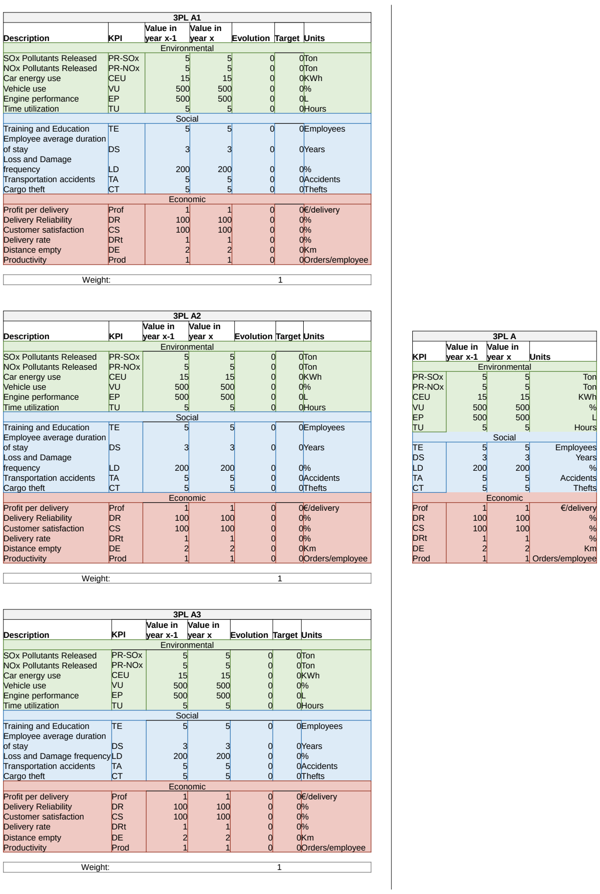
Social					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
TE		Number of employees that have attended any kind of training course	5	5	Employees
DS		Number of years an employee remains in the industry	3	3	Years
LD	Number of damaged items delivered	DD	1	1	Items
	Number of lost items	LI	1	1	Items
	Number of deliveries planned	D	1	1	Deliveries
TA		Number of accidents occurred during the transportation	5	5	Accidents
CT		Number of theft events during transportation	5	5	Thefts

Output Data

Processing the values inserted

3PL A1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
SOx Pollutants Released	PR-SOx	5	5	0		Ton
NOx Pollutants Released	PR-NOx	5	5	0		Ton
Car energy use	CEU	15	15	0		KWh
Vehicle use	VU	500	500	0		%
Engine performance	EP	500	500	0		L
Time utilization	TU	5	5	0		Hours
Social						
Training and Education	TE	5	5	0		Employees
Employee average duration of stay	DS	3	3	0		Years
Loss and Damage frequency	LD	200	200	0		%
Transportation accidents	TA	5	5	0		Accidents
Cargo theft	CT	5	5	0		Thefts
Economic						
Profit per delivery	Prof	1	1	0		€/delivery
Delivery Reliability	DR	100	100	0		%
Customer satisfaction	CS	100	100	0		%
Delivery rate	DRt	1	1	0		%
Distance empty	DE	2	2	0		Km
Productivity	Prod	1	1	0		Orders/employee

Figure D.7: 3PLA 1 sheet



3PL A1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
SOx Pollutants Released	PR-SOx	5	5	0	0	Ton
NOx Pollutants Released	PR-NOx	5	5	0	0	Ton
Car energy use	CEU	15	15	0	0	KWh
Vehicle use	VU	500	500	0	0	%
Engine performance	EP	500	500	0	0	L
Time utilization	TU	5	5	0	0	Hours
Social						
Training and Education	TE	5	5	0	0	Employees
Employee average duration of stay	DS	3	3	0	0	Years
Loss and Damage frequency	LD	200	200	0	0	%
Transportation accidents	TA	5	5	0	0	Accidents
Cargo theft	CT	5	5	0	0	Thefts
Economic						
Profit per delivery	Prof	1	1	0	0	€/delivery
Delivery Reliability	DR	100	100	0	0	%
Customer satisfaction	CS	100	100	0	0	%
Delivery rate	DRt	1	1	0	0	%
Distance empty	DE	2	2	0	0	Km
Productivity	Prod	1	1	0	0	Orders/employee

Weight:	1

3PL A2						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
SOx Pollutants Released	PR-SOx	5	5	0	0	Ton
NOx Pollutants Released	PR-NOx	5	5	0	0	Ton
Car energy use	CEU	15	15	0	0	KWh
Vehicle use	VU	500	500	0	0	%
Engine performance	EP	500	500	0	0	L
Time utilization	TU	5	5	0	0	Hours
Social						
Training and Education	TE	5	5	0	0	Employees
Employee average duration of stay	DS	3	3	0	0	Years
Loss and Damage frequency	LD	200	200	0	0	%
Transportation accidents	TA	5	5	0	0	Accidents
Cargo theft	CT	5	5	0	0	Thefts
Economic						
Profit per delivery	Prof	1	1	0	0	€/delivery
Delivery Reliability	DR	100	100	0	0	%
Customer satisfaction	CS	100	100	0	0	%
Delivery rate	DRt	1	1	0	0	%
Distance empty	DE	2	2	0	0	Km
Productivity	Prod	1	1	0	0	Orders/employee

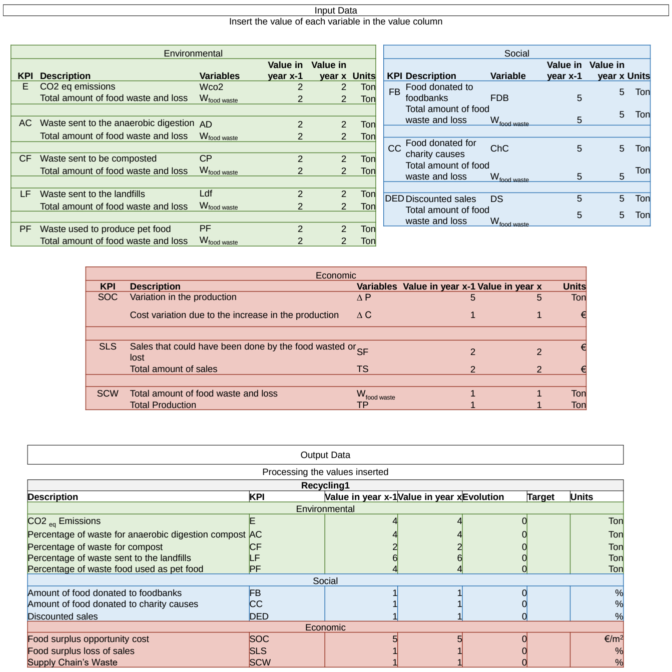
Weight:	1

3PL A3						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
SOx Pollutants Released	PR-SOx	5	5	0	0	Ton
NOx Pollutants Released	PR-NOx	5	5	0	0	Ton
Car energy use	CEU	15	15	0	0	KWh
Vehicle use	VU	500	500	0	0	%
Engine performance	EP	500	500	0	0	L
Time utilization	TU	5	5	0	0	Hours
Social						
Training and Education	TE	5	5	0	0	Employees
Employee average duration of stay	DS	3	3	0	0	Years
Loss and Damage frequency	LD	200	200	0	0	%
Transportation accidents	TA	5	5	0	0	Accidents
Cargo theft	CT	5	5	0	0	Thefts
Economic						
Profit per delivery	Prof	1	1	0	0	€/delivery
Delivery Reliability	DR	100	100	0	0	%
Customer satisfaction	CS	100	100	0	0	%
Delivery rate	DRt	1	1	0	0	%
Distance empty	DE	2	2	0	0	Km
Productivity	Prod	1	1	0	0	Orders/employee

Weight:	1

3PL A			
KPI	**Value in year x-1**	**Value in year x**	**Units**
Environmental			
PR-SOx	5	5	Ton
PR-NOx	5	5	Ton
CEU	15	15	KWh
VU	500	500	%
EP	500	500	L
TU	5	5	Hours
Social			
TE	5	5	Employees
DS	3	3	Years
LD	200	200	%
TA	5	5	Accidents
CT	5	5	Thefts
Economic			
Prof	1	1	€/delivery
DR	100	100	%
CS	100	100	%
DRt	1	1	%
DE	2	2	Km
Prod	1	1	Orders/employee

Figure D.8: 3PLA 1 sheet



Input Data

Insert the value of each variable in the value column

Environmental					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
E	CO2 eq emissions	Wco2	2	2	Ton
	Total amount of food waste and loss	$W_{food\ waste}$	2	2	Ton
AC	Waste sent to the anaerobic digestion	AD	2	2	Ton
	Total amount of food waste and loss	$W_{food\ waste}$	2	2	Ton
CF	Waste sent to be composted	CP	2	2	Ton
	Total amount of food waste and loss	$W_{food\ waste}$	2	2	Ton
LF	Waste sent to the landfills	Ldf	2	2	Ton
	Total amount of food waste and loss	$W_{food\ waste}$	2	2	Ton
PF	Waste used to produce pet food	PF	2	2	Ton
	Total amount of food waste and loss	$W_{food\ waste}$	2	2	Ton

Social					
KPI	**Description**	**Variable**	**Value in year x-1**	**Value in year x**	**Units**
FB	Food donated to foodbanks	FDB	5	5	Ton
	Total amount of food waste and loss	$W_{food\ waste}$	5	5	Ton
CC	Food donated for charity causes	ChC	5	5	Ton
	Total amount of food waste and loss	$W_{food\ waste}$	5	5	Ton
DED	Discounted sales	DS	5	5	Ton
	Total amount of food waste and loss	$W_{food\ waste}$	5	5	Ton

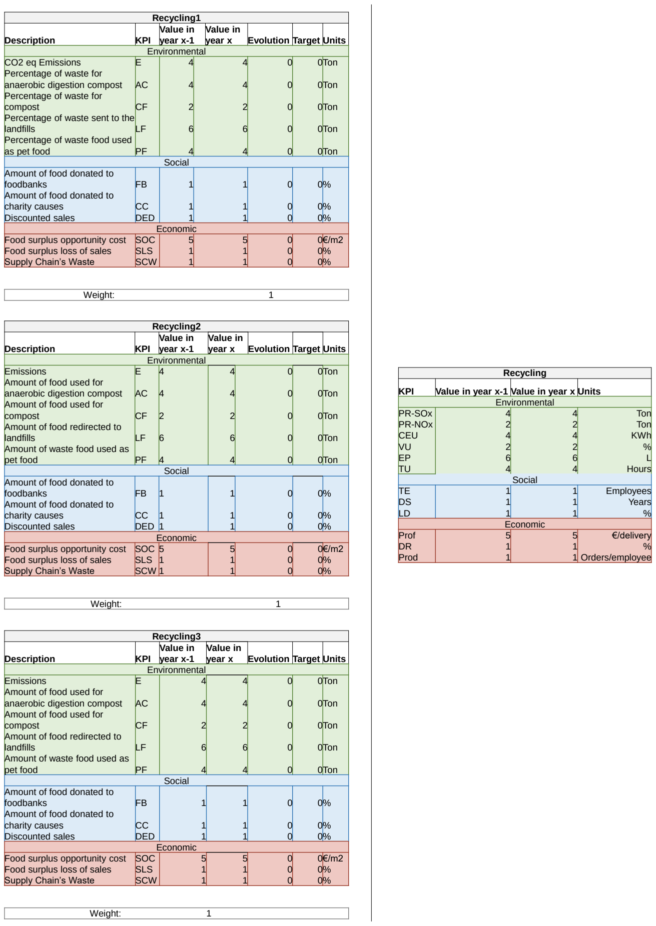
Economic					
KPI	**Description**	**Variables**	**Value in year x-1**	**Value in year x**	**Units**
SOC	Variation in the production	ΔP	5	5	Ton
	Cost variation due to the increase in the production	ΔC	1	1	€
SLS	Sales that could have been done by the food wasted or lost	SF	2	2	€
	Total amount of sales	TS	2	2	€
SCW	Total amount of food waste and loss	$W_{food\ waste}$	1	1	Ton
	Total Production	TP	1	1	Ton

Output Data

Processing the values inserted

Recycling1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
CO2 $_{eq}$ Emissions	E	4	4	0		Ton
Percentage of waste for anaerobic digestion compost	AC	4	4	0		Ton
Percentage of waste for compost	CF	2	2	0		Ton
Percentage of waste sent to the landfills	LF	6	6	0		Ton
Percentage of waste food used as pet food	PF	4	4	0		Ton
Social						
Amount of food donated to foodbanks	FB	1	1	0		%
Amount of food donated to charity causes	CC	1	1	0		%
Discounted sales	DED	1	1	0		%
Economic						
Food surplus opportunity cost	SOC	5	5	0		€/m^2
Food surplus loss of sales	SLS	1	1	0		%
Supply Chain's Waste	SCW	1	1	0		%

Figure D.9: Recycling 1 sheet



Recycling1						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
CO2 eq Emissions	E	4	4	0	0	Ton
Percentage of waste for anaerobic digestion compost	AC	4	4	0	0	Ton
Percentage of waste for compost	CF	2	2	0	0	Ton
Percentage of waste sent to the landfills	LF	6	6	0	0	Ton
Percentage of waste food used as pet food	PF	4	4	0	0	Ton
Social						
Amount of food donated to foodbanks	FB	1	1	0	0	%
Amount of food donated to charity causes	CC	1	1	0	0	%
Discounted sales	DED	1	1	0	0	%
Economic						
Food surplus opportunity cost	SOC	5	5	0	0	€/m2
Food surplus loss of sales	SLS	1	1	0	0	%
Supply Chain's Waste	SCW	1	1	0	0	%

Weight: 1

Recycling2						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Emissions	E	4	4	0	0	Ton
Amount of food used for anaerobic digestion compost	AC	4	4	0	0	Ton
Amount of food used for compost	CF	2	2	0	0	Ton
Amount of food redirected to landfills	LF	6	6	0	0	Ton
Amount of waste food used as pet food	PF	4	4	0	0	Ton
Social						
Amount of food donated to foodbanks	FB	1	1	0	0	%
Amount of food donated to charity causes	CC	1	1	0	0	%
Discounted sales	DED	1	1	0	0	%
Economic						
Food surplus opportunity cost	SOC	5	5	0	0	€/m2
Food surplus loss of sales	SLS	1	1	0	0	%
Supply Chain's Waste	SCW	1	1	0	0	%

Weight: 1

Recycling3						
Description	**KPI**	**Value in year x-1**	**Value in year x**	**Evolution**	**Target**	**Units**
Environmental						
Emissions	E	4	4	0	0	Ton
Amount of food used for anaerobic digestion compost	AC	4	4	0	0	Ton
Amount of food used for compost	CF	2	2	0	0	Ton
Amount of food redirected to landfills	LF	6	6	0	0	Ton
Amount of waste food used as pet food	PF	4	4	0	0	Ton
Social						
Amount of food donated to foodbanks	FB	1	1	0	0	%
Amount of food donated to charity causes	CC	1	1	0	0	%
Discounted sales	DED	1	1	0	0	%
Economic						
Food surplus opportunity cost	SOC	5	5	0	0	€/m2
Food surplus loss of sales	SLS	1	1	0	0	%
Supply Chain's Waste	SCW	1	1	0	0	%

Weight: 1

Recycling			
KPI	**Value in year x-1**	**Value in year x**	**Units**
Environmental			
PR-SOx	4	4	Ton
PR-NOx	2	2	Ton
CEU	4	4	KWh
VU	2	2	%
EP	6	6	L
TU	4	4	Hours
Social			
TE	1	1	Employees
DS	1	1	Years
LD	1	1	%
Economic			
Prof	5	5	€/delivery
DR	1	1	%
Prod	1	1	Orders/employee

Figure D.10: Recycling sheet