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The Role of Green Information System in Promoting Green Innovation in the Food and Beverage Sector

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Table of Contents

List of figures

List of tables

Abstract

The Food and Beverage (F&B) sector, a significant contributor to environmental degradation, faces increasing pressure to reduce its carbon footprint and adopt more sustainable practices. In this context, innovation has emerged as a key factor, though its implementation is particularly challenging due to cost constrains, regulatory uncertainties and other conflicting goals regarding products' characteristics, such as cost, taste and nutrition. In this context, the thesis investigates the role of Green Information Systems (Green IS), which are digital platforms designed to track environmental data and support decision making processes in the field of sustainability, as possible enablers of green innovation in the F&B industry.

Adopting a qualitative, multi-case study approach, the research combines an overview of Green IS tailored to the F&B sector, with interviews conducted across eight organizations (four F&B companies and four Green IS providers) in the UK and Italy. The study explores three research questions: (1) What are the drivers that motivate F&B companies to implement Green IS? (2) To what extent can Green IS enable green innovation? (3) Can Green IS address the challenges that characterize green innovation processes?

Findings indicate that companies adopt Green IS primarily to enhance brand image, gain a competitive advantage, credibly communicate environmental performance and compensate for internal knowledge gaps. Although innovation is rarely the initial motivation for adoption, it often emerges as an indirect yet valuable outcome. In several cases, Green IS have acted as catalysts for serendipitous innovation by revealing environmental hotspots that triggered reformulations or supply chain adjustments.

This work also highlights how specific Green IS functionalities help address challenges in green innovation. In fact, supplier engagement tools enable upstream collaboration and data sharing, reducing uncertainty and supporting more sustainable sourcing. Integration with R&D systems allows environmental data to inform product development from early stages, facilitating trade-off decisions. Hotspot identification and scenario modelling provide visibility into the environmental impact of design choices, guiding firms in prioritizing actions. Finally, automated life cycle assessments offer standardized and credible reports that strengthen both internal alignment and external communication. In conclusion, while Green IS are not yet systematically adopted with innovation-oriented goals, their ability to overcome key challenges and support evidence-based decision-making processes make them powerful enablers of green transformation in the F&B sector.

1. Introduction

Environmental sustainability has emerged as a defining challenge for the manufacturing sector, influencing strategic priorities across industries. Companies today face mounting pressures to reduce their environmental footprint. In this context, sustainability is no longer a secondary concern, but a central element of strategic decision-making. Among industrial sectors, the food and beverage (F&B) industry stands out due to its considerable reliance on natural resources, its complex and often global supply chains, and its significant contribution to environmental degradation. According to *Crippa et al. (2021),* food systems are estimated to be responsible for roughly 34% of all annual anthropogenic greenhouse gas (GHG) emissions, with the majority of them linked to agricultural production and land use.

As the sector confronts the challenges of climate change, resource scarcity, and shifting consumer expectations, innovation is increasingly seen as the pathway through which sustainability goals can be achieved. However, implementing green innovation within the food and beverages (F&B) sector presents distinctive challenges. The industry is characterized by low profit margins, strong cost pressures, and high dependence on supply chain partners, all of which complicate efforts to develop and scale sustainable solutions (*Dangelico and Pujari, 2010*). Moreover, tensions between short-term operational priorities and long-term environmental objectives are particularly pronounced in this sector, where companies must balance sustainability, competitiveness, and consumer satisfaction.

To address these complexities, digital transformation and the integration of data-driven solutions have become increasingly vital (*Meemken et al. 2024*). In particular, Green Information Systems (Green IS) are gaining attention for their potential to enhance environmental transparency, support regulatory compliance, and guide sustainability-oriented decision-making. These systems offer functionalities that extend beyond monitoring emissions, enabling firms to assess environmental performance, simulate scenarios, reformulate products, and engage supply chain partners in sustainability efforts (*Steininger et al., 2022*).

Despite their growing relevance, the role of Green IS in enabling green innovation remains relatively underexplored in the academic literature. This gap is particularly evident in the F&B industry, where digital tools are still at an early stage of adoption, and their use for innovation purposes is often secondary to reporting or branding goals.

In such a context, this thesis seeks to investigate how environmental objectives are embedded within innovation processes in the F&B sector and to examine the challenges and tensions that companies face when pursuing green innovation. The study specifically explores the extent to which Green IS support these processes, both by enabling sustainability-oriented product strategies and by helping firms navigate trade-offs and organizational tensions.

To achieve this aim, the research first reviews the literature on environmental sustainability, green innovation, and Green IS, with particular attention to the F&B context. Drawing on this review, a set of research questions is developed to address identified gaps. These are then examined through a qualitative, multi-case study methodology involving both Green IS providers and food and beverage companies. Specifically, eight companies were interviewed: four F&B companies and four environmental platform providers specialized in the food sector. By focusing on this intersection, the research offers possibly novel insights into the strategic role of Green IS as enablers of environmental innovation.

The thesis is structured into five chapters. Chapter 2 reviews the relevant literature, including sustainability trends in the F&B sector, the drivers and barriers to green innovation, and the functionalities of Green IS. Chapter 3 outlines the research methodology, with a focus on the qualitative case study approach. Chapter 4 presents the empirical findings and discusses how Green IS are used in practice to support innovation and manage tensions. Finally, Chapter 5 offers conclusions, identifies theoretical and practical implications, and suggests directions for future research.

2. Background and literature review

2.1 Environmental sustainability in the food and beverage sector

The food and beverage (F&B) sector is under increasing pressure to reduce its environmental footprint. As a significant contributor to global GHG emissions, resource depletion, and pollution, the sector faces complex and urgent sustainability challenges that require systemic and innovative responses. This section explores the main environmental impacts associated with the F&B industry, with a particular focus on the importance of tracking and measuring environmental data. It also examines both the legal requirements and voluntary frameworks that guide environmental information reporting for companies operating in this sector.

2.1.1 Environmental sustainability trends and challenges in the food and beverage sector

The food and beverage (F&B) sector face a range of complex and urgent sustainability challenges, with one of the most significant being its environmental impact. In particular, the sector is a major contributor to global GHG emissions. According the the Intergovernmental Panel on Climate Change (*IPCC, 2022*), an estimated 21–37% of total GHG emissions associated with human activities originate from food systems. The majority of these emissions stem from land use (24%), crop production (27%) and livestock and fish farms (31%), while packaging, processing, transport and retail contribute a smaller share (18%) as illustrated in Figure 1.

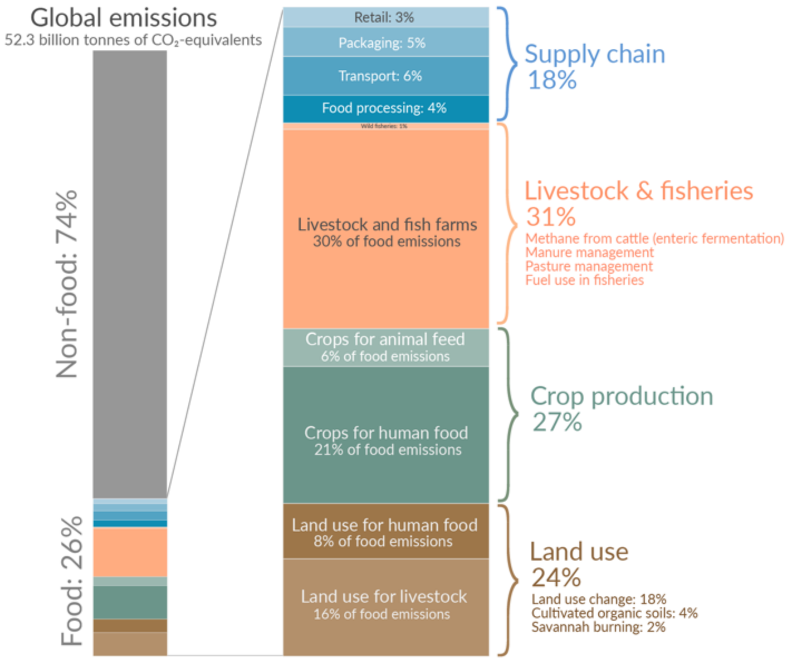

Figure 1: Global greenhouse gas emissions from food production
Source: Ritchie, 2019

Future projections pose further challenges. The global population is expected to surpass 10 billion by 2050, increasing demand for food and intensify pressure on land, water and energy resources. Nutritional challenges also pose a major concern. Globally, around 35% of adults are overweight and more than half a billion of them are obese (*WHO, 2011*). At the same time, approximately 850 million people are undernourished; and an estimated 735 million remain at risk of hunger (*FAO, 2024*). Furthermore, the food system also impacts other aspects of public health through exposure to agrochemicals (e.g. pesticides and fertilisers) and other pollutants in ground water (such as manure). In this context, *Willett et al., (2019)* argue that transforming the food system is essential to feed a growing global population in a more equitable and sustainable way.

Given its importance, this section explores key sustainability trends and other associated issues that the F&B sector is facing in terms of sustainability impact.

Agriculture impact. Agriculture is the largest contributor to food-related environmental impacts, accounting for nearly half of food systems emissions in developed countries and proportionally more in developing regions, where post-harvest infrastructure is limited. Other critical issues include the use of chemical inputs (pesticides, fungicides, insecticides), soil degradation from tilling, and resulting negative impacts on water quality, aquatic ecosystems and marine biodiversity. Broader concerns involve industrial feed production, eutrophication, deforestation, biodiversity loss, and emissions from land conversion and agricultural machinery.

Packaging. As food supply chains have become increasingly complex and globally dispersed, food products often travel long distances before reaching end consumers. This has made it essential to ensure that food remains fresh, safe, and intact throughout the distribution process. Packaging plays a critical role in preserving food quality by slowing deterioration and maintaining both nutritional value and visual appeal. Among the various materials used for food packaging, plastic remains the most prevalent. According to *UNEP (2018)*, nearly 40% of all plastic produced globally is used in packaging for F&B. While recycling has long been promoted as a sustainable solution, it is often insufficient. Most recycled plastic materials undergo downcycling, a process through which their quality and structural integrity are progressively reduced, eventually rendering them unusable. In addition, many food containers are single-use, non-compostable, and difficult to recycle, largely due to contamination from food residues. Consequently, achieving a balance between effective food protection and environmental sustainability remains a considerable challenge. Growing consumer awareness of the ecological and health impacts associated with non-degradable packaging has led the packaging industry to intensify its efforts toward sustainability. This includes not only reducing the overall use of packaging but also exploring more environmentally responsible alternatives. One promising direction involves the development of reusable packaging systems, along with innovative materials that are easier to recycle, compost, reuse, or biodegrade, thereby minimizing environmental impact. Notable examples of these alternatives include packaging derived from corn starch, popcorn, and mushrooms, as well as biodegradable plates, cutlery, and containers made from agro-industrial waste, such as avocado pits.

Food Lost and Waste. According to the Food and Agriculture Organization (*FAO, 2011*), approximately 1.052 billion tonnes of food are wasted every year, roughly one third of all food produced for human consumption. This waste contributes to around 10% of greenhouse gas emissions from food systems. One of the main challenges in addressing food waste is the difficulty of accurately measuring losses and tracking progress over time. The urgency of tackling this issue is reflected in the United Nations Sustainable Development Goals, particularly in SDG 12, which promotes sustainable consumption and production. A key target under this goal is to "halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" by 2030.

Food loss and waste occur at every stage of the supply chain (upstream and downstream) from primary production to consumption in households. Understanding where and how much food is wasted across these stages is essential for designing effective interventions, establishing baselines, and measuring progress toward reduction targets. As illustrated in Figure 2 about half of food lost or wasted every year happens upstream: during the harvest, postharvest handling and storage, and processing stages (*McKinsey et al., 2022*).

Major sources of food loss in the supply chain include harvest losses, which result from improper techniques or timing during harvesting, or when products fails to meet cosmetic standards *(Kumar and Kalita, 2017*). Storage losses are often linked to poor moisture control, contamination, and temperature fluctuations. Processing losses involve reductions in the quantity or quality of food during manufacturing stages, while distribution losses further contribute to the overall problem (*Murphy et al. , 2024*). In addition, the generation of food waste is closely connected to the efficiency of the supply chain itself. Factors such as procurement challenges, limited market access for small-scale farmers, strict quality requirements, and disruptions within market systems all play a role in the volume of food discarded.

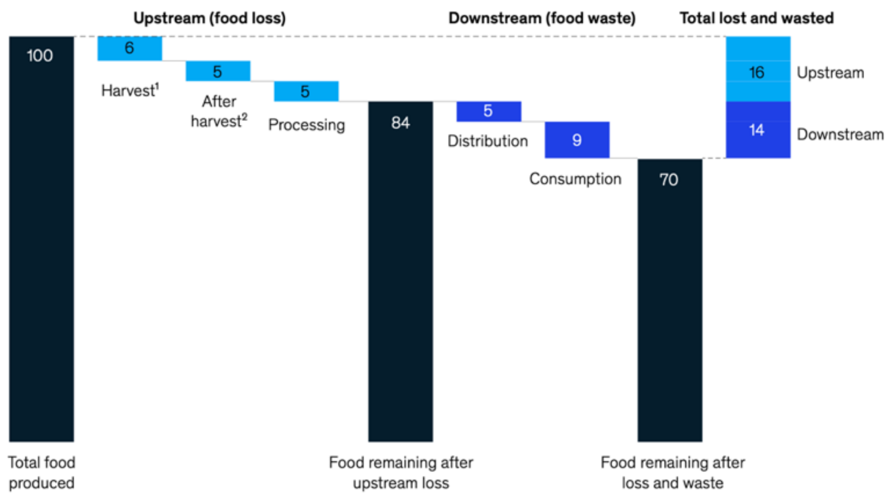

Figure 2: Global food loss and waste, by value chain step, % of production (Reported in primary crops for crops, carcass weight for meat, weight equivalent for fish, and total production leaving manufacturer for processed commodities)
Sources: McKinsey 2022

Alternative proteins. A growing body of research has demonstrated that meat and dairy products contribute disproportionately to environmental degradation, particularly through high GHG emissions. Alternative proteins, which included any protein-rich ingredients derived from plants, insects, fungi, algae, or animal cells, offers a promising pathway for the consumption of protein-dense foods with a significantly lower environmental impact compared to conventional livestock products (*Talwar et al. 2024*). These ingredients give rise to three main categories of alternative protein products, each characterized by distinct process and value chains: (1) plant-based products; (2) cultured or cultivated meat; and (3) precision fermentation (*Aminetzah et al., 2025*). Plant-based proteins, often derived from plants and fungi, are formulated to replace animal proteins in traditional recipes and food applications. Cultured meat, in turn, refers to actual animal tissue developed from animal cells in a controlled environment. Precision fermentation, meanwhile, uses microbial organisms to produce key components such as flavors, fats and enzymes, which are then incorporated into plant-based or cultivated products (*Miranda and Rodrigues, 2023*). As the sector evolves a growing number of "hybrid" products have emerged–combination of technology production–illustrated in Figure 3.

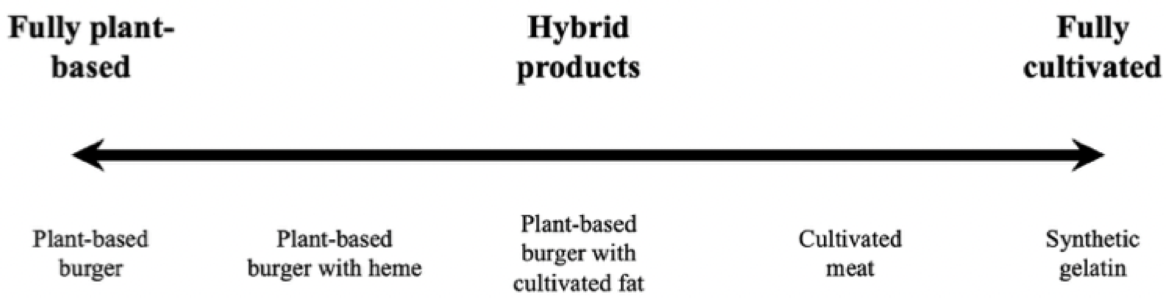

Figure 3: Alternative proteins' products
Source: Aminetzah et al. 2025

Among the various alternative proteins solution, plant-based products have become the most widely implemented: animal-based products are responsible for 57% of emissions, compared to just 29% from plant-based alternatives (*Xu et al., 2021*). As illustrated in Figure 4 animal-based products, particularly beef and cow milk, are the largest contributors to total GHG emissions, accounting for 25% and 10% respectively. Those types of products are increasingly seen as a means to promote healthier and more sustainable diets, given that they typically require fewer natural resources, such as land and water, and are generally higher in dietary fibre than animal-derived proteins. Once confined to niche markets, plant-based alternatives are now entering the mainstream. Recent surveys show that in Italy approximately 83% of consumers are willing to substitute beef with plant-based options at least once a week (*Rizzo et al. 2023*). This consumer shift, often driven by so-called "climavores," individuals who choose their diet based on its climate impact, presents a unique opportunity for food producers. By integrating plant-based proteins into their offerings, companies can simultaneously address sustainability goals and cater to the preferences of environmentally conscious consumers.

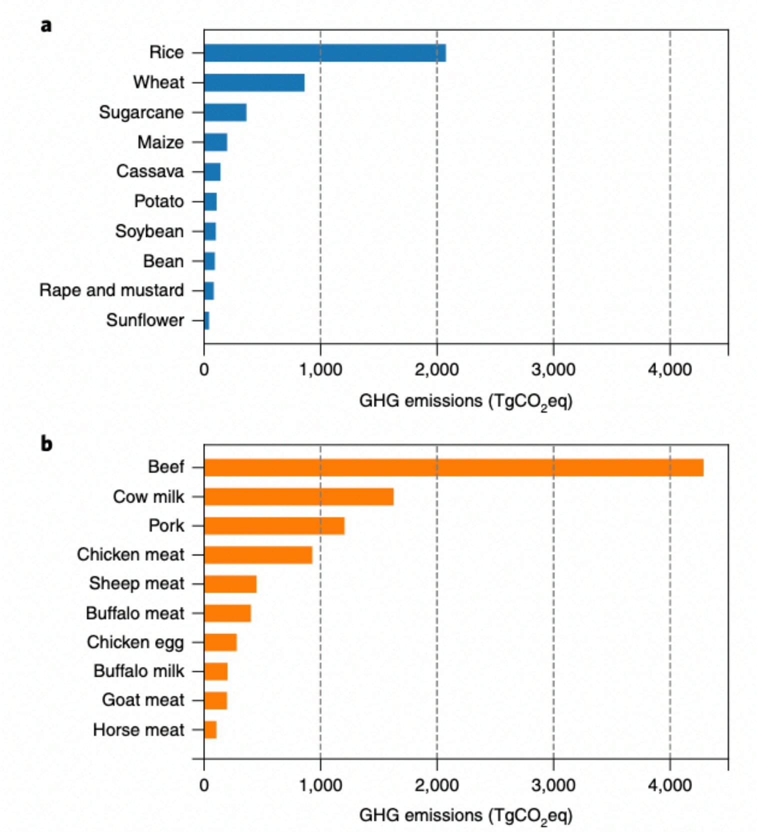

Figure 4: GHG emissions from the productions of top-contributing commodities
a. Top ten plant-based food commodities b. Top ten animal-based food commodities
Source: Xu et al. 2021

2.1.2 Tracking and calculating environmental information in the food and beverage sector

Several different methods can be used to assess the environmental impact of the F&B sector. Among these, the most widely adopted is the estimation of GHG emissions. However, GHGs are only one aspect of environmental impact, and a comprehensive evaluation should also account for other critical dimensions, such as waste generation and water consumption. Despite this, GHGs calculations remain the most commonly used and standardized approach for environmental assessment in the sector.

Nonetheless, estimating GHG emissions within the food system remains highly complex. This is due to the sector's intricate and globalized supply chains and to the fact that certain emissions, such as those related to the transport of inputs or production of plastics for packaging, are traditionally allocated to other sectors (*Mbow et al., 2019*). The transition from traditional, local food systems to increasingly globalized value chains further increases system complexity and stakeholder interdependencies (*FAO, 2024*). Improving transparency using an open-source global dataset could play a key role in advancing sustainable food systems, and databases could be a key enabler towards more transparency and support the transition to sustainable food systems. A major limitation also lies in the absence of a standardized and harmonized approach for measuring, reporting and verifying data on emissions data. In fact, standards around carbon accounting are open to interpretation, which means that data, where it does exist, is impossible to compare. The calculation of GHG emissions also depends on the boundaries and objectives that are considered. In fact, it is possible to calculate the carbon footprint of an entire company or of a single product, as will be discussed in the next section, which focuses on relevant standards.

One of the most widely used methods for assessing the environmental impact of a product is the calculation of its carbon footprint. In the case of food products, this refers to the total amount of GHG emissions generated across its lifecycle, expressed in kilograms of CO2-equivalents. Product carbon footprints can be defined on a 'cradle to grave' basis: this includes emissions from every stage: from production (including all agricultural inputs, machinery, livestock, and soil used) to processing, transportation, preparation, and final disposal. (*FAO, 2015*). Other approaches are possible too, such as 'cradle to farm gate' or 'cradle to purchase'. However, the emphasis here is on a 'cradle to gate' approach, where each actor in the supply chain focuses on calculating product carbon footprints of the product life cycle up to the point where the product leaves its premises (Figure 5).

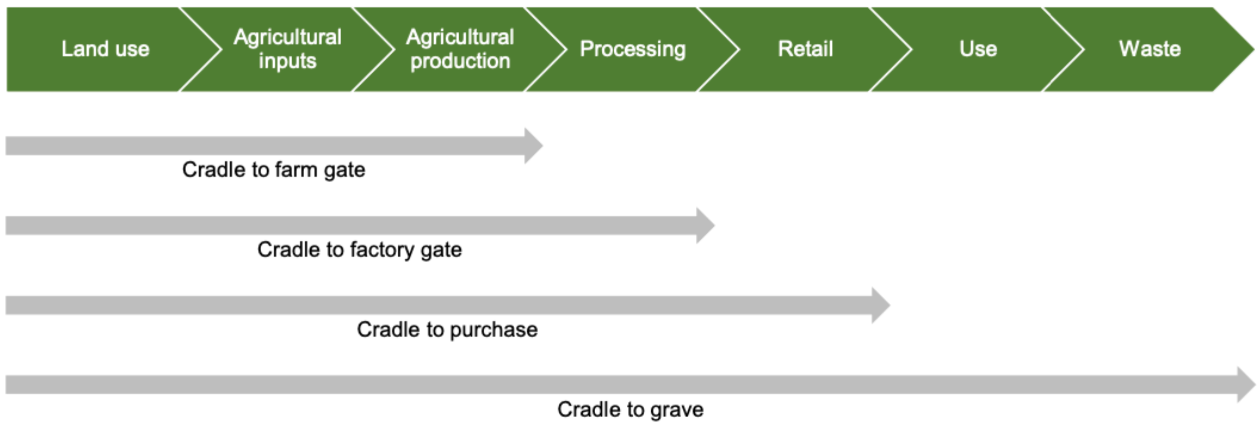

Figure 5: Stages of the product life cycle
Source: OECD, 2025

Understanding and managing **Product Carbon Footprints (PCFs)** is also becoming increasingly essential for F&B companies. In fact, PCFs offer valuable insights that help businesses improve their environmental performance, meet regulatory requirements, and align with broader sustainability goals. By identifying emission hotspots, such as raw material sourcing, logistics, or packaging, companies can take targeted action to reduce their climate impact. Moreover, analysing PCFs can highlight operational inefficiencies, enabling cost reductions and overall performance improvements.

To standardize emissions reporting, the GHG Protocol framework divides emissions into three scopes. Scope 1 includes direct emissions from owned or controlled sources; Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating, and cooling; and Scope 3 encompasses all other indirect emissions that occur in a company's value chain. Scope 3 itself is subdivided into 15 categories, accounting for both upstream and downstream activities (WBCSD & WRI, 2004). For Scope 2, two accounting methods are recognized: the location-based method and the market-based method (*Brander, 2018*). Accurate reporting across all three scopes remains a challenge, especially Scope 3, which is often underreported due to its complexity and data limitations. Together with the relatively poor reporting of Scope 3 emissions, studies suggest that the F&B industry needs to urgently improve its GHG emissions management overall in order to better understand current and expected future emissions.

As mentioned earlier, **quantifying food waste** is also essential for developing effective reduction and valorisation strategies. The FLW Protocol, launched in 2013, provides standardized tools for measuring food loss and waste, outlining what to measure and how to do it (*FLW Protocol, 2016*). It identifies ten methods for quantification based on measurement or estimation, as shown in Figure 6 Among these, the most significant methods include direct weighting, which is the most accurate approach, using scales to measure waste. However, this method can be costly and logistically challenging. Another important method is waste composition analysis, which involves sorting waste to understand the types and amounts of food being discarded. Lastly, mass balance estimates food waste by comparing inputs and outputs within a process, making it especially useful in industrial settings. These methods (summarized in Figure 6) are crucial for building accurate food waste inventories and supporting the development of effective strategies to reduce waste. In this field, in the UK, the WRAP (Waste and Resources Action Programme)'s *Food Waste Reduction Roadmap* helps businesses reduce waste through a simple three-step approach: Target, Measure, Act. First, businesses set a clear reduction target, ideally aiming to cut food waste by 50% by 2030. Then, they measure and report waste data using standardized methods to track progress. Finally, they act by preventing waste in operations, working with suppliers, and supporting consumers to reduce food waste.

	METHODS	DEFINITION
MEASUREMENT OR APPROXIMATION An entity can use these methods if it can get direct access to the FLW	**1. Direct weighing**	Using a measuring device to determine the weight of FLW
	2. Counting	Assessing the number of items that make up FLW and using the result to determine the weight; includes using scanner data and "visual scales"[a]
	3. Assessing volume	Assessing the physical space occupied by FLW and using the result to determine the weight
	4. Waste composition analysis	Physically separating FLW from other material in order to determine its weight and composition
	5. Records	Using individual pieces of data that have been written down or saved, and that are often routinely collected for reasons other than quantifying FLW (e.g., waste transfer receipts or warehouse record books)
	6. Diaries	Maintaining a daily log of FLW and other information
	7. Surveys	Gathering data on FLW quantities or other information (e.g., attitudes, beliefs, self-reported behaviors) from a large number of individuals or entities through a set of structured questions
	METHODS	**DEFINITION**
INFERENCE BY CALCULATION	**8. Mass balance**	Measuring inputs (e.g., ingredients at a factory site, grain going into a silo) and outputs (e.g., products made, grain shipped to market) alongside changes in levels of stock and changes to the weight of food during processing
	9. Modeling	Using a mathematical approach based on the interaction of multiple factors that influence the generation of FLW
	10. Proxy data	Using FLW data that are outside the scope of an entity's FLW inventory (e.g., older data, FLW data from another country or company) to infer quantities of FLW within the scope of the entity's inventory

Figure 6: Methods of quantifying FLW
Source: FLW Protocol, 2016

Water consumption is another key environmental concern in the F&B sector, which is one of the most water-intensive industries globally. Water is used extensively across all stages of the supply chain, from crop irrigation and animal husbandry to food processing, cleaning, and packaging (Mekonnen and Gerbens-Leenes, 2020). To assess and manage this impact, the concept of *water footprint* is widely used. It quantifies the total volume of freshwater used, both directly and indirectly, in the production of a product and is typically broken down into blue water (surface and groundwater), green water (rainwater stored in the soil), and grey water (freshwater required to dilute pollutants to acceptable levels). Figure 7 illustrates the water footprint of selected crop and animal products measured in terms of physical weight (L/kg) nutritional energy content (L/kcal). On average, animal-based foods have a substantially higher water footprint than plant-based foods providing the same nutritional energy. For instance, the average water footprint per calorie for beef is approximately 20 times greater than of cereals and starchy roots. Hoekstra (2017) further demonstrated that replacing meat-based diets with nutritionally equivalent plant-based diets could reduce the overall water footprint of consumption by 36% in industrial countries and by 15% in developing countries.

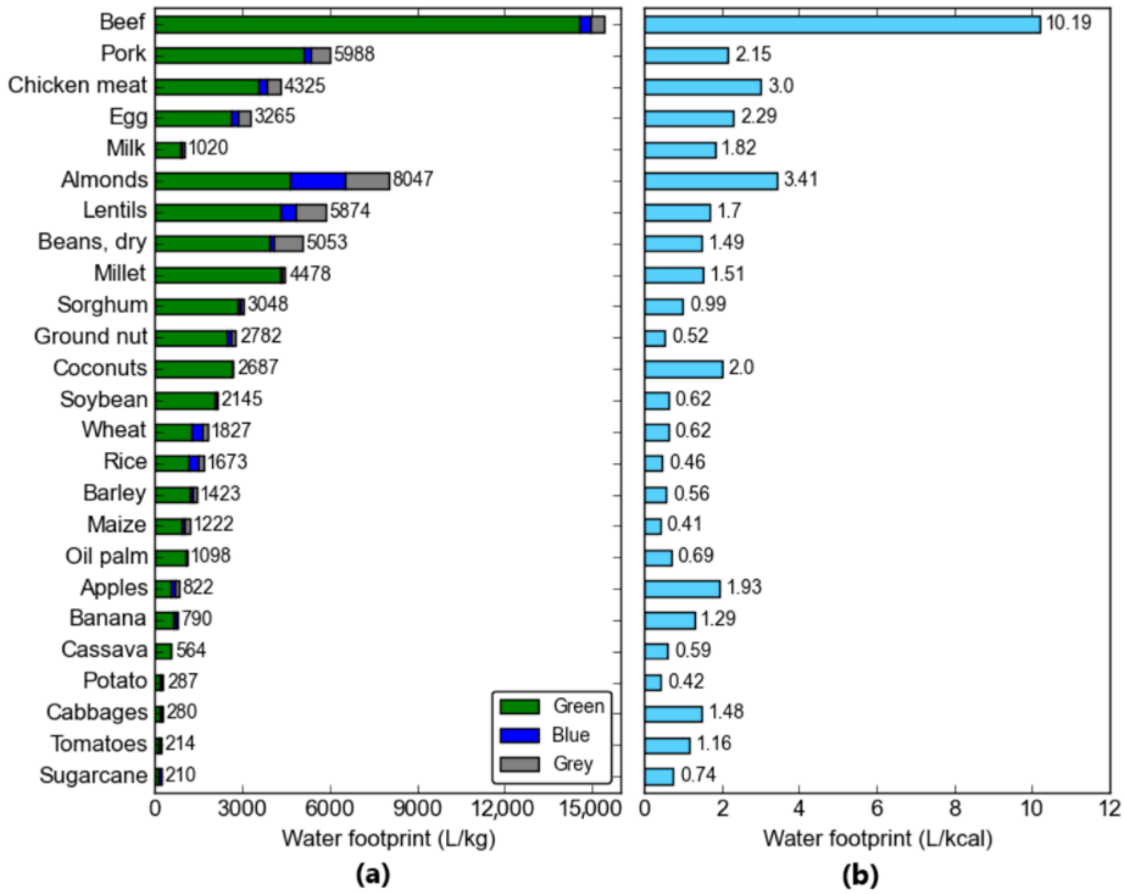

Figure 7: The Water Footprint of selected crop and animal products
*(a) WF in a liter of water per kg of product, (**b**) WF in a liter of water per kcal of nutritional energy contained in the product. Data source from (b) WF in a liter of water per kcal of nutritional energy contained in the product.*
Source: Mekonnen and Gerbens-Leenes, 2020

Another key methodological tool for assessing the environmental performance of products and process is the **Life Cycle Assessment**. Unlike approaches that focus exclusively on carbon emission, after providing an overview of the main environmental impacts and types of data that can be measured, Life Cycle Assessment (LCA) emerges as a multi-criteria methodology that goes far beyond simply calculating the carbon footprint. It relies on detailed environmental data to assess a wide range of impacts, such as resource use, water consumption, acidification, and ecotoxicity, across the entire life cycle of a product or process. This makes LCA a valuable tool for developing a comprehensive and scientifically grounded understanding of sustainability. By definition LCA is the ‘‘compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle.’’ The ISO 14040 series of standards issued by the International Organization for Standardization (ISO) defines the principle to develop an LCA and identifies 4 iterative phases: goal and scope definition, inventory analysis, impact assessment, and interpretation.

An important distinction relies on the difference between *attributional* and *consequential* approach to life cycle assessment. Attributional LCA is essentially a "snapshot" at a point in time of the flows that can be ascribed to a given product or system, whereas consequential LCA asks how these would change if for example output was increased by one uni. LCA studies have been applied to assess a number of food products, for instance to identify potential mitigation opportunities by changing production practices, to assess novel zoo-technical practices, and to suggest preferable options in comparative assessments (*Cucurachi et al. 2019*). While LCA have traditionally been ex post conducted of well-established product systems, currently LCA studies are starting to be conducted at the earlier stage of research and development for food systems in order to maximize the potential for sustainability by design (*Cucurachi et al. 2019*).

Given the complexity and the wide range of methodologies used to calculate environmental impact, numerous standards and guidelines have been developed over the past two decades to promote consistency and enable meaningful comparisons. Due to the specific characteristics of certain industries, sector-specific standards have also been introduced to offer more targeted guidance. This is particularly relevant in sectors such as F&B, which is the focus of this research. These are visually represented as a pyramid in the Figure 8 below. In this figure, the standards and guidelines on the left primarily address firm-level (or farm-level) carbon footprints, whereas those on the right focus on product-level carbon footprints. Those at the bottom of the pyramid are more general in scope, while those towards the top become increasingly specific, targeting particular sector such as agriculture or sub-sectors like dairy, beef or horticulture.

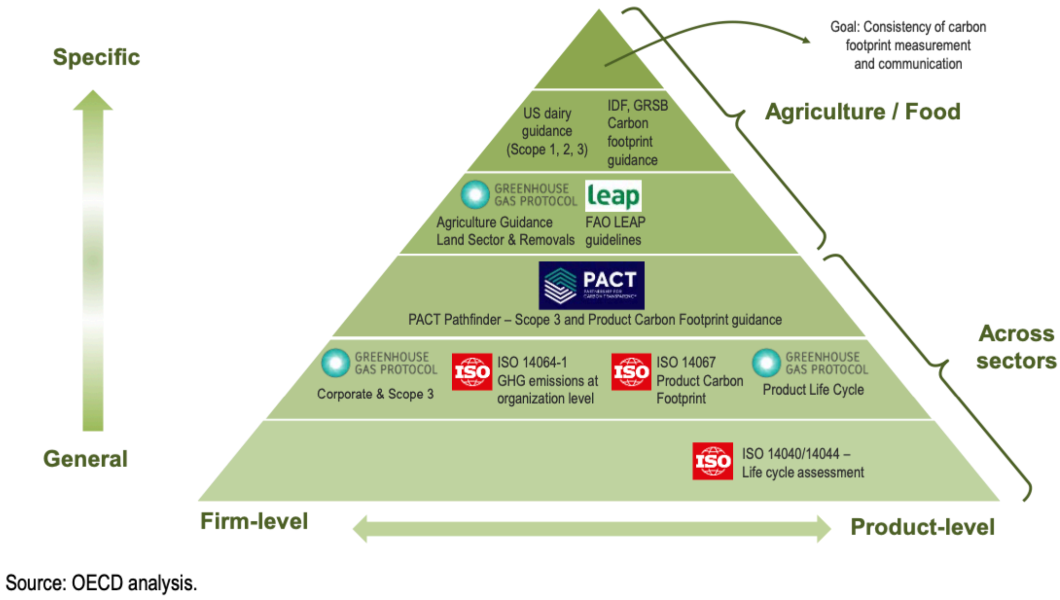

Figure 8: Standards and guidelines in the food sector
Source: OECD 2025

As is clear from Figure 8, the two main standard-setting bodies across sectors are the Greenhouse Gas Protocol (GHG Protocol) and ISO.

Focusing of the product level, the basic principles of LCA are defined in the widely used **ISO 14040** and **14044 standards**. **ISO 14067**, the standard for product carbon footprints, builds upon and complements these guidelines. This standard outline key principles for conducting product carbon footprint assessments, emphasizing relevance, completeness, consistency, coherence, accuracy, and transparency. These principles ensure that assessments are based on reliable data, follow internationally recognized methods, and produce results that are comparable, verifiable, and clearly documented. In addition to the ISO 14067 standard (first introduced in 2013, revised in 2018, and currently under revision), other key product carbon footprint standards include the GHG Protocol Product Life Cycle Accounting and Reporting standard (introduced in 2011) and the PAS 2050 standard (which was the developed by the British Standards Institute in 2008).

The GHG Protocol's Product Standard and the PAS 2050 specify accounting principles similar to these. All three standards aim to ensure the credibility of carbon footprint estimates by reducing both systematic and non-systematic errors. However, they present some differences. One of the main differences is the hierarchy of allocation. ISO 14067 and the GHG Protocol prioritize physical relationships; PAS 2050 gives precedence to supplementary sectoral guidance and economic allocation. Another area where standards differ is in their exclusion criteria: ISO 14067 and the GHG Protocol offer flexibility by allowing exclusions that do not significantly alter results or when data are insignificant. PAS 2050 is more prescriptive, allowing exclusions only when emissions are below

1% of total emissions and provided that at least 95% of total emissions are accounted for. An additional distinction lies in the fact that ISO 14067 standard can accommodate both attributional or consequential approaches, but firm-level and product-level carbon footprints typically take an attributional lens (GHG Protocol, 2022[4]); the GHG Protocol Product Standard even requires it (GHG Protocol, 2011[5]).

Since existing standards do not address all methodological challenges, additional guidance is needed to ensure consistency in carbon footprint assessment. One of such initiatives is the **PACT Pathfinder Framework**, developed under the Partnership for Carbon Transparency (PACT), which aims to harmonize Scope 3 emissions reporting and improve data exchange across complex supply chains. The framework proposes a hierarchical approach: companies should prioritize product category rules (PCRs) when available. In the absence, firm should refer to sector-specific rules or cross-sectoral standards such as ISO 14067, combined with PACT guidance. Emissions should be calculated using cradle-to-gate boundaries, based on primary data when available, or high-quality secondary data. For multi-output processes, the framework recommends avoiding allocation where possible, otherwise applying system expansion or economic/physical allocation based on context. The framework also provides initial guidance on how to account for emissions from land use change and land management, while noting that this will be aligned with the forthcoming GHG Protocol Land Sector and Removals Guidance. Finally, it defines minimum data quality and verification requirements for exchanging product-level emissions data across supply chains.

As we move up the pyramid and focus more specifically on food systems, relevant guidance includes the **GHG Protocol's Agriculture Guidance** and the forthcoming Land Sector and Removals Guidance. These documents help apply the GHG Protocol standards, particularly for corporate and Scope 3 reporting. The agricultural Guidance details how to account for carbon stocks (in biomass, dead organic matter, soil organic matter, and harvested products) and how firms should report their GHG fluxes (i.e. emissions and removals). While the forthcoming Land Sector Guidance may replace this document, it has not yet been published at the time of writing.

Although ISO 14040/14044 and ISO 14067 offer broad methodological direction, assessing product carbon footprints requires more specific guidance to avoid inconsistent results. Product Category Rules (PCRs) address this need by standardizing methods and datasets for particular product types. In the food sector, relevant PCRs include the Product Environmental Footprint Category Rules (PEFCRs) for dairy (covering milk, butter, cheese, etc.), beer, animal feed, pet food, and pasta, with additional rules for marine fish under development. However, some stakeholders have expressed concerns that existing PEFCRs may introduce new inconsistencies (*Foundation Earth, 2023*). Other PCRs come from sector organizations. For example, the **International Dairy Federation (IDF)** has its own Global Carbon Footprint standard (latest version 2022), and it aims to harmonize carbon footprint methodologies and improve consistency across dairy-related assessments. It offers detailed recommendations on system boundaries, allocation rules, land use change, and carbon sequestration. Similar initiatives include the **Global Roundtable for Sustainable Beef's standard (GRSBS)** and the HortiFootprint category rules, which precede the PEFCR for horticulture.

Despite the large number of standards and guidelines available, measuring environmental impact in the F&B sector remains highly complex. This is partly due to the diversity within the sector itself, which often requires category-specific rules and methodologies. Another challenge lies in the inconsistencies created by the coexistence of multiple standards. As previously noted, even small differences between them can lead to significantly different results. This creates confusion for companies that want to measure the carbon footprint of their products or operations, but struggle to determine which method is most appropriate or required in their specific case (*OECD 2025).*

2.1.3 Legal reporting obligations and voluntary disclosure in the food and beverage sector

In recent years, the F&B industry has been increasingly subject to pressure for greater transparency and accountability across its operations. This has resulted in the proliferation of both mandatory reporting obligations, particularly in the domain of environmental, social, and governance (ESG) sustainability, and voluntary initiatives aimed at showcasing positive environmental and social impacts. These voluntary frameworks have gained significant importance as companies seek to differentiate themselves and align with evolving stakeholder expectations.

For firms operating within the F&B sector, a clear understanding of reporting standards is essential to ensure compliance and maintain competitiveness. Beyond the mere communication of sustainability initiatives, companies are increasingly expected to provide verifiable, data-driven evidence of their impact. In this context, digital tools play a critical role, offering enhanced capabilities for the efficient, reliable, and accurate collection, management, and analysis of sustainability-related data.

The main mandatory obligation in the F&B sector, particularly within the European context, around sustainability is the *Corporate Sustainability Reporting Directive (CSRD).* The *CSRD* represents a significant evolution in the European Union's regulatory framework for sustainability disclosure. It is set to replace the existing Non-Financial Reporting Directive (NFRD), which has been in force since 2014 and requires large companies to disclose their environmental, social, and governance (ESG) performance alongside financial reporting. A central element of CSRD is the double materiality assessment, which forms the foundation of the report. This assessment evaluates how the company influences sustainability issues (inside-out perspective) and how those same issues affect the company (outside-in perspective). The first implementation phase, starting in 2025, will affect companies that are already subject to the NFRD, which will now be required to transition to the more demanding CSRD framework for the financial year 2024. In the second phase, beginning in 2026, the obligation will extend to large companies that meet at least two of the following criteria: more than 250 employees, over €40 million in net turnover, or a balance sheet total exceeding €20 million. The third phase, scheduled for 2027, will apply to listed small and medium-sized enterprises (SMEs), while the final phase in 2028 will cover non-EU companies with at least one subsidiary operating within the EU and generating over €150 million in turnover within the EU market. Table 1 provides and overview of the adoption requirements per year. Companies that fall under the scope of CSRD will need to develop more advanced systems for data collection, verification, and reporting in line with the European Sustainability Reporting Standards (ESRS). As a result, CSRD not only reinforces the importance of sustainability accountability but also raises the bar for operational transparency and traceability across global supply chains.

CORPORATE SUSTAINABILITY REPORTING DIRECTIVE (CSRD)				
Year	**2025**	**2026**	**2027**	**2028**
Who	**Companies reporting with NFRD**	**Companies with over: >250 employees >€40 million net sales >€20 million balance sheet total**	**Listed SMEs**	**Non-EU companies with one subsidiary in the EU >€150 million sales in the EU**

Table 1: CSRD adoption per year
Source: author's own elaboration based on EU CSRD guidelines

The European Deforestation Regulation (EUDR) is a legislative initiative introduced by the European Union to ensure that all products placed on, imported into, or exported from the EU market are compliant with deforestation-free requirements. The regulation applies to products containing any of the seven commodities identified as posing a high risk of deforestation: soy, beef, palm oil, wood, cocoa, coffee, and rubber. According to the EUDR, these products must provide verifiable proof that they do not originate from land that was deforested after 31 December 2020. Although initially expected to enter into force earlier, the implementation of the EUDR has been postponed to December 2025. This presents a significant challenge for F&B manufacturers, who must trace the origin of every ingredient within their supply chains. Given the complexity and global nature of these supply chains, ensuring traceability and accurately mapping and registering data requires substantial financial investment and robust technological infrastructure.

The analysis of current regulations reveals that regulatory pressure is increasingly targeting large companies. However, in the coming years, sustainability reporting will become mandatory for a broader range of businesses. For this reason, companies should start preparing by familiarizing themselves with the requirements and investing in sustainability initiatives. Proactively engaging with the CSRD can help reduce risks, enhance market competitiveness, and unlock new investment opportunities.

In addition to mandatory frameworks, many companies in the sector follow voluntary sustainability standards (VSS), which are private norms used to ensure transparency and responsible practices across production, processing, and distribution stages. The most important VSS are represented in Figure 9 and may relate to product characteristics or organizational practices. These standards help firms differentiate themselves in the market and signal commitment to sustainable practices.

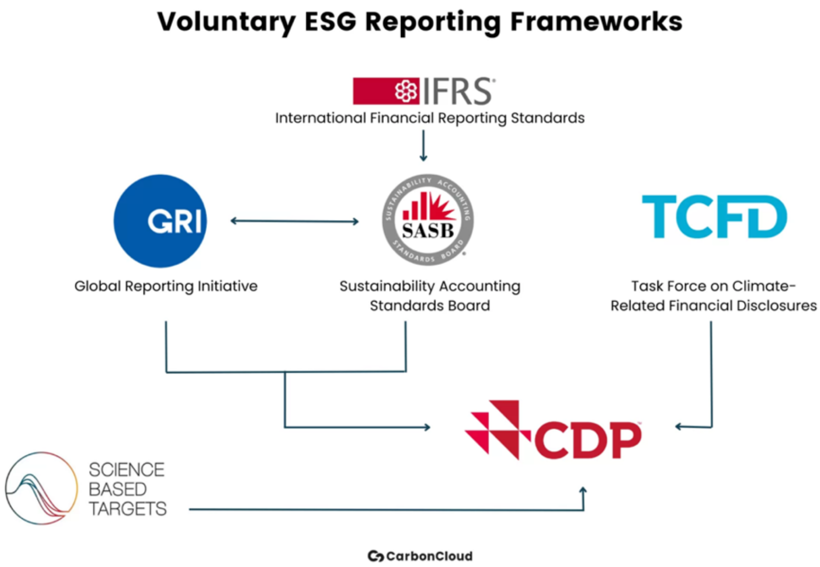

Figure 9: Voluntary ESG Reporting Frameworks
Source: CarbonCloud, 2023

Among the most widely adopted voluntary sustainability frameworks, the *Science-Based Targets initiative (SBTi)* stands out for its rigorous approach to corporate climate action. Developed through a partnership between the United Nations, WWF, CDP, and the World Resources Institute, the initiative provides companies with clear guidance to align their emissions reduction strategies with the objectives of the Paris Agreement. SBTi targets are structured around several key elements. Companies begin by selecting the type of target, such as absolute or intensity-based emissions reductions, renewable energy targets, or value chain engagement targets. These are then framed within a defined time horizon, typically setting near-term goals five to ten years from a chosen base year, which must be no earlier than 2015 and reflective of the company's emissions profile. Targets are applied to Scope 1, 2, and/or 3 emissions, depending on their nature, with some, like engagement targets, being scope-specific. In addition, companies choose whether to follow a general reduction pathway or a sector-specific one**,** when available. A recent development within the Science-Based Targets initiative is the introduction of *FLAG (Forest, Land and Agriculture)* guidance, launched in 2022. This methodology is specifically designed for sectors with significant land-related emissions, such as agriculture, forestry, and food production. For the F&B industry, the FLAG framework is particularly relevant, as many emissions come from land use, deforestation, soil degradation, and livestock farming, among others. These emissions often fall outside conventional energy-related reporting and require a separate approach. Under FLAG, companies must measure and report land-based emissions separately from their Scope 1, 2, and 3 inventories, and set specific reduction targets aligned with global climate limits. Incorporating FLAG allows F&B companies to better manage the footprint of high-impact commodities like meat, dairy, grains, or palm oil, improving the credibility of their climate strategies and increasing transparency along the supply chain.

Any company committed to SBTi is encouraged to report annually to *Carbon Disclosure Project (CDP)*, a non-profit organization that operates a global environmental disclosure system. Through it, report environmental data, including GHG emissions, water usage, and deforestation impacts, is possible by submitting a CDP questionnaire annually and inviting suppliers to disclose to CDP as well. Moreover, CDP's Supply Chain Program enables companies to collect environmental data from their suppliers, encouraging upstream sustainability and transparency. This is especially relevant for F&B firms, which often source ingredients globally and operate in complex supply chains. Given the sector's high exposure to environmental risks, especially those related to agriculture, water consumption and deforestation, CDP data support companies in identifying environmental hotspots in their supply chains, assessing risks and align with climate target (*CDP Reporting Guidance, 2023*).

In addition, the *Global Reporting Initiative (GRI)* is one of the most widely adopted frameworks for sustainability reporting, designed to help organizations communicate their environmental, social, and economic impacts in a standardized and transparent manner. Established in the late 1990s, GRI has evolved into a globally recognized standard-setter, promoting accountability and stakeholder engagement across industries. Unlike disclosure initiatives aimed primarily at investors, such as the

Carbon Disclosure Project (CDP), GRI adopts a broader stakeholder approach, encouraging organizations to consider the needs and expectations of customers, employees, regulators, and communities. The GRI Standards include both universal and topic-specific disclosures, and in 2021 the organization released updated sector-specific standards, including those tailored for agriculture. In particular, GRI 13 applies to companies involved in the primary production of food, including farming, livestock, aquaculture, and fishing. The standard emphasizes the sector's dependence on and impact on natural ecosystems, biodiversity, and labor-intensive practices (*GRI 13, 2023*).

Talking about voluntary ESG reporting standard is necessary to cite the *Sustainability Accounting Standards Board (SASB)*. SASB has a particularly important role for companies operating in the F&B sector. SASB provides industry-specific standards for identifying and disclosing ESG risks and opportunities that may have a financial impact in the short, medium, or long term. Covering a broad range of issues—from greenhouse gas emissions and land use to labor practices and supply chains—SASB is especially relevant for F&B companies, which typically operate within complex, resource-intensive value chains. Since 2022, SASB standards have been managed by the International Sustainability Standards Board (ISSB) and are undergoing alignment with the Global Reporting Initiative (GRI), promoting coherence between investor-oriented and stakeholder-focused reporting frameworks.

Finally, the *Task Force on Climate-Related Financial Disclosures (TCFD),* offers a clear and widely adopted framework for reporting on climate-related risks and strategies, structured around four key areas: Governance, Strategy, Risk Management, and Metrics & Targets. For F&B firms whose exposure to climate risks is heightened by reliance on agriculture, water, energy, and long supply chains, the TCFD approach supports a more structured understanding of how climate change may affect operations, sourcing, and market positioning. Moreover, TCFD-aligned disclosure is increasingly required by regulation in several countries and overlaps with the data expectations of other initiatives such as CDP. For F&B companies aiming to improve climate resilience, manage investor expectations, and demonstrate accountability, the integration of SASB and TCFD frameworks provides a robust foundation for sustainability governance and transparent communication.

2.2 Green innovation

In the face of intensifying regulations, resource scarcity, and growing consumer demand for sustainable products, green innovation has emerged as a strategic imperative across multiple industries, including the F&B sector. Green innovation offers a critical pathway for companies to reduce their environmental footprint while remaining competitive and responsive to evolving market expectations. As sustainability becomes an increasingly important driver of business transformation, a clear understanding of the nature, drivers, and challenges of green innovation is essential.

This chapter introduces the concept of green innovation and explores its various definitions and related terms. It distinguishes between product and process innovation, as well as between radical and incremental innovation, emphasizing their specific characteristics in the context of green, as opposed to conventional innovation. Furthermore, the chapter examines key insights from the literature regarding the main drivers and challenges that influence the development of green innovation. Special attention is given to the F&B sector, highlighting industry-specific dynamics, recent advancements, and emerging opportunities.

2.2.1 Defining green innovation

Green Innovation is a specific type of innovation whose main objective is to mitigate and/or avoid environmental damage, while protecting the environment and enabling companies to satisfy new consumer demands, create value, and increase yields (*Albort-Morant et al. 2017*). Green innovation can be therefore viewed as the development of green processes or products with reduced environmental impacts, aiming for resources and energy conservation, waste and pollution prevention, recycling, and reuse, among other goals (*Chen et al., 2006*). Alternatively, green innovation can be seen as a set of innovations that help organizations achieve economic benefits by reducing their environmental footprint, thus meeting environmental objectives (*Wong et al. 2014*).

Several other terms are closely related to green innovation:

- *eco-innovation*: involves the creation, assimilation or exploitation of a product, production process, service, or management method that is new to the organization developing or adopting it. The Organization for Economic Co-operation and Development (OECD) defines eco-innovation as "the development of products (goods and services), processes, marketing methods, organizational structure, and new or improved institutional arrangements, which, intentionally or not, contribute to a reduction of environmental impact in comparison with alternative practices" (*OECD, 2009*);
- *environmental innovation*: refers to a set of techniques, systems, products and/or new or modified processes that aim to prevent or reduce environmental damage (*Kemp,2010*);
- *sustainable innovation*: is defined as "the integration of conservation and development to ensure that modifications to the planet do indeed secure the survival and well-being of all people" (*Albort-Morant et al. 2017*).

In this thesis, the term GI is used as a synonym for environmental/ecological innovation, encompassing all changes in the product portfolio or production processes aimed at achieving sustainability goals, such as waste management, eco-efficiency, emissions reduction, recycling, eco-design, or any other actions implemented by companies to reduce their environmental footprint (De Marchi 2022). While sustainability-driven innovation will be mentioned in this thesis, it will not be the primary focus of the research, as it encompasses broader goals beyond environmental concerns, including innovations aimed at generating societal benefits. In the F&B sector, this can involve not only reducing the environmental footprint but also developing products that are healthy and nutritionally valuable.

In the context of green innovation, it is essential to distinguish between product and process innovations, as each entails different strategies and environmental implications across the value chain. Process innovation refers to improvements in production or delivery methods and can occur at various levels, from minor adjustments to complete redesigns of processes or even entire industry value chains. Historically, this form of innovation has been more prevalent, as it directly involves activities under the control of firms (Lee and Min, 2015). In the F&B sector, typical examples include wastewater treatment, solid waste management, material recycling, or energy recovery systems, all of which aim to reduce the environmental footprint of industrial operations (Triguero and Sáez-Martinez, 2018). On the other hand, product innovation focuses on enhancing both the technological features of goods or services to lower their overall environmental impact. In the F&B domain, this may involve the development of organic products or foods with improved nutritional profiles, which are commonly cited as examples of eco-product innovation (Triguero and Sáez-Martinez, 2018). According to Dangelico and Pujari (2010), green product innovation is a multidimensional process that typically targets three key environmental aspects, materials, energy, and pollution across different stages of a product's physical life cycle: production, use, and disposal.

Indeed, innovation can involve major and minor changes. The OECD's Oslo Manual (OECD, 2025) distinguishes between radical innovations, which represent fundamental changes that can be revolutionary in terms of technology or market, and incremental innovations, which involve a minor degree of novelty. Radical green product innovations may include the use of new technologies or the replacement of critical components that significantly reduce a product's overall environmental impact. In contrast, incremental green innovations may involve increasing use of existing product features such as eco-efficiency, substituting conventional materials with those that have a lower environmental impact, or designing recyclable products (De Angelico, 2018).

In the food sector, examples of incremental eco-innovations might include the application of advances in biotechnology. At the same time, radical green innovations could involve the use of novel protein foods or food additives based on nanomaterials to reduce the use of natural resources (Triguero and Sáez-Martinez, 2018) , or the introduction of eco-friendly insecticides.

Building upon the concept of New Product Development (NPD)**,** some studies have defined Environmental New Product Development (ENPD) as the integration of environmental issues into product development processes to create products with minimal environmental impact (*Pujari et al., 2003*). The design-for-environment approach means that ENPD is not a radically different process compared to conventional NPD, but that it does involve an additional level of complexity. The key differences between ENPD and conventional NPD include a broader consideration of customer satisfaction, a focus on the physical life cycle of products, design for post-use applications, and an expanded perspective on the supply chain (*Pujari et al., 2003).*

2.2.2 Drivers and challenges in green innovation.

To analyze green innovation effectively, it is essential to understand the drivers and challenges that companies face. The next section provides a categorization of the different types of drivers and challenges, building upon the existing literature on the topic.

Drivers:

External drivers include **regulatory pressure**, which is often a primary motivator for companies to develop eco-innovations, frequently driven by the need to comply with environmental standards rather than purely sustainability goals (*Bossle et al., 2016*). Several empirical studies confirm that regulatory push and pull mechanisms foster the development of eco-innovations across multiple industries (*De Marchi, 2012*). **Market demand** is another important driver, as consumer preferences, driven by factors like Corporate Social Responsibility (CSR) and the increasing demand for sustainable products, significantly influence companies' decisions to invest in eco-innovations (*Bossle et al., 2016*). **Collaboration** is also a key external driver. Collaborative networks, including partnerships with clients, competitors, universities, and research centers, are crucial for knowledge acquisition and the development of innovative solutions (*De Marchi, 2012*). Collaboration with suppliers is also essential to ensure the availability of eco-friendly inputs and components, which may not be readily available in the market (*De Marchi, 2012*).

Internal drivers include **efficiency improvements**, such as cost reduction, equipment updates, investments in R&D, and certifications ([Green et al., 1994](#)). **Environmental capability** and managerial concerns, including environmental leadership, also play an important role in driving green innovation ([Chen et al., 2012](#); [Eiadat et al., 2008](#)). This include the quality of human resources, including training and participation in sustainability programs, as well as a company's environmental strategy, including its overall culture and environmental goals, are also key factors that drive the adoption of green innovation ([Bossle et al. 2016](#)).

Table 2 summarizes the drivers behind the development of green innovations, distinguishing between internal and external factors.

INTERNAL DRIVERS	**Regulatory pressure**	External rules or laws pushing companies to adopt eco-innovations for compliance.
	Market demand	Consumer interest in sustainable products driving companies to innovate.
	Collaboration	Partnerships with suppliers, clients, or institutions to develop green solutions.
EXTERNAL DRIVERS	**Efficiency improvements**	Internal efforts to reduce costs and resource use, often leading to greener practices.
	Environmental capability	A company's internal skills, leadership, and strategy focused on sustainability.

Table 2: Drivers for the development and adoption of Green Innovations
Source: author's elaboration

Challenges:

Despite a number of potential benefits, companies also face several challenges when developing GIs, particularly in new product development for reducing environmental impacts (Table 3).

Cost is one of the most significant barriers to the adoption of greener products, as initial investment in green technologies can be high, and the resulting products may not be competitive from a pricing perspective. This is why, without government subsidies or government rebate to customers, companies often find it difficult to compete with brands and companies who have not invested in green technologies ([Dangelico and Pujari, 2010).](#) **Technological complexity** is another challenge, as developing products with reduced environmental impacts often requires knowledge and skills beyond the traditional industry expertise ([De Marchi, 2012](#)). **Uncertainty** regarding market and technological aspects is also a significant challenge, due to the lack of established standards or accepted technologies for measuring environmental performance. While eco-labels and third-party certifications could help address this issue, some product categories still lack such recognition

(Dangelico and Pujari, 2010). **Consumer awareness** is another challenge. The absence of universally recognized standards for environmental performance makes it difficult for consumers to trust and differentiate green products. **Communication and organizational challenges** are prevalent, particularly when managing information flows and coordinating resources for eco-certifications or eco-labels inside the organization (Dangelico and Pujari, 2010). **Cultural resistance** within organizations can also hinder the integration of environmental concerns into business processes, often requiring strong leadership and active support from top management (Pujari et al., 2003).

CHALLENGES	
Cost	High investment and lack of price competitiveness make green products less attractive.
Technological complexity	Requires advanced knowledge beyond traditional industry expertise.
Uncertainty	Lack of clear standards and technologies for environmental performance.
Consumer awareness	Consumers struggle to recognize or trust green products due to unclear labeling.
Communication	Internal difficulties in managing eco-labeling and certifications.
Organizational resistance	Cultural barriers and lack of internal support slow down sustainability integration.

Table 3: Challenges in the development and adoption of Green Innovations
Source: author's elaboration

2.2.3 Green innovation in the F&B sector

With regard to Green Innovation, the F&B sector has traditionally been viewed as a low-tech sector. However, recent advancements in industrial processing and packaging technologies, along with the introduction of new products, highlight how food companies are accumulating valuable knowledge through non-R&D activities. This is particularly relevant in the shift toward eco-innovation that faces sustainability challenges related to food safety and energy efficiency in processing (Triguero et al., 2022).

Furthermore, the literature on sustainable innovation in the F&B sector distinguishes between two approaches: *retro-innovation*, which focuses on product reformulation, the use of organic raw materials, and sustainable packaging, and *forward-looking innovation*, which involves the integration of new technologies and the development of novel products (Leon-Bravo et al., 2019). This distinction calls for further exploration, as each approach addresses different dimensions of sustainability in food production.

Despite growing scholarly attention to the theme of green innovation, research remains largely focused on high-tech sectors, leaving resource-intensive industries such as F&B underexplored (*Ben Amara and Chen, 2022)*

2.2.4 Tensions and trade-offs: general overview

One of the aims of this thesis is to understand what are the tensions and trade-offs that may arise during green innovation processes. Despite the importance of this issue, few studies have explicitly addressed it, particularly in the F&B sector.

The discussion around tensions in green innovation is complex due to its intrinsic characteristics, such as high level of uncertainty and advanced technological requirements (*De Marchi, 2012*). Consequently, a comprehensive analysis of the tensions is still lacking. To fully grasp the nature of trade-off and tensions involved in GI, it is essential to review the literature on tensions arising at the intersection of innovation and environmental sustainability and the approached to solve these tensions.

Given the terminology complexity in this field, this research adopts the definitions provided by *Wannags and Gold (2020)*:

- A *tension* is a paradox in which two elements, when considered individually, seem reasonable, but create an illogical relationship when examined together.
- A *trade-off,* on the other hand, refers to situations where a sacrifice in one area is necessary to achieve benefits in another, so it refers to cases in which two or more conflicting goals are present. As stated by *Byggeth and Hochschorner (2006),* "a trade-off occurs when it is impossible to optimize all factors at once".

Innovation processes are characterized by opposing forces that companies must balance, such as innovation speed, development costs and product quality (*Lin et al.* 2012). In the context of sustainability, environmental, social and circular aspects must also be considered (Parolin et al., 2025; *Dangelico and Pujari, 2010).* Balancing these objective is particularly difficult because product development is a complex and interactive process, making difficult to predict in advance when and which trade-offs will arise (Byggeth e Hochschorner, 2006). Conflicting objectives can also lead to coordination challenges and organizational paralysis, as employees struggle to identify actions that simultaneously improve all goals, especially when tasks are interdependent (*Ethiraj et al. 2009*). However, conflicts can also act as drivers for innovation as they stimulate creative solutions and organizational change (*Vollmer, 2015*; *Dyer and Song, 2003).* In fact conflicts, when strategically managed, can be a valuable asset for fostering innovation within organizations (Dyer and Song, 2003).

In the context of F&B sector the problem of conflicting goals is particularly important because several objectives must be considered in the development of a new product. An example is the tension between taste and sustainability objective. *Erhard et al. (2024)* for example, analyses how to address these conflicting goals in order to follow costumer preferences.

The literature on tensions in corporate sustainability is quite broad so a few classification can be made.

First of all tensions can be classified on the basis of the level at which they occur. At the strategic (macro) level, tensions involve the decision of whether a company should engage in sustainability initiatives or not and it is related to the intrinsic conflicting nature of environmental, social and financial goals. While at the tactical and operational (micro) level, tensions concern which areas of sustainability should be addressed and which guiding principles should be followed (*Parolin et al., 2025*). Apart from this classification there is also another type of tensions that are also related to the organizational level aring due to the intrinsic conflicting nature of environmental, social and financial goals.

Focusing on the *macro-level* tensions, two main approaches to analyze corporate sustainability and its related problems and trade-offs can be found in the literature: the instrumental and the integrated view.

- The *instrumental view* prioritizes the economic goals over social and environmental ones. In this view, sustainability is persued when it aligns with financial performance and, as a result, tensions and conflicts are overlooked (*Hanh 2015*). This approach focuses exclusively on situations where there is an alignment between financial, environmental and social goals, excluding cases where these aspects are in conflict.
- The *integrated view*, increasingly adopted in recent years, is rooted in paradox theory that claims that opposing elements needs to be embraced and managed rather than being eliminated. This perspective argues that companies must simultaneously pursue different sustainability objectives across all three dimensions (environmental, social and financial) even when they appear contradictory (*Hanh et al. 2010*).

At the *micro-level*, [Di Paola et al. (2021)] examine tensions in environmental innovation as opposing elements of its characteristics, such as types, force and modes of innovation. These tensions can be those between the normative environment and competitive pressure, between internal investment and knowledge collaboration and between market and non-market forces.

Hanh 2015 identifies four main categories of organizational tensions. First, the *conflict between individual and organizational sustainability agendas* arises when employees' personal beliefs about sustainability conflict with the organization's structure, culture, or strategy. This tension often results from structural elements like compensation or reporting systems that limit employees' ability to act on their values. Second, the tension between *short-term and long-term orientation* arise from the difference in time horizons. Sustainable development requires a long-term perspective, while organizations typically focus on short-term goals. This creates conflicts between immediate benefits and long-term sustainability outcomes. Third, *the tension between isomorphism and structural or technological change* occurs when organizations face pressure to conform to established practices while also needing to innovate for sustainability. This can clash with institutional expectations, as seen in the automotive industry's struggle with adopting low-emission vehicles. Lastly, the *tension between efficiency and resilience* arises from the conflict between optimizing for efficiency and maintaining system resilience. While efficiency through standardization can improve organizational performance, it often reduces diversity, which is essential for resilience. The Irish potato famine illustrates this tension, where the focus on high-yield, homogeneous crops led to vulnerability. The first two tensions are more relevant at the individual and organizational levels, while the latter two occur at the organizational and systemic levels.

Among these, the short-term vs long-term tension is particularly relevant in green innovation. In fact, radical product innovation often leads to significant changes such as making existing products obsolete and enabling entire markets to emerge, transform, or disappear. However it requires a systemic change in both infrastructure and consumer behaviour (*Dangelico and Pujari, 2010*).

2.2.5 Approaches to manage tensions and trade-offs

In order to address conflicting performance goals and avoid organization paralysis *Ethiraj et al. 2009* identify three possible strategies:

- *Goal Myopia*: Focusing on a single goal at a time simplifies decision-making, enabling incremental progress. This myopic focus paradoxically improves overall performance across all goals by breaking the impasse of conflicting priorities.

- *Spatial Differentiation*: Assigning distinct goals to different departments (e.g., R&D focuses on innovation, production on cost efficiency) reduces local complexity. This compartmentalization allows subunits to specialize without being overwhelmed by cross-goal trade-offs.
- *Temporal Differentiation*: Rotating goals over time (e.g., prioritizing market share growth in one quarter and profitability in the next) provides clarity while ensuring all objectives receive attention cyclically.

Salvato and Rerup (2018) for example, building on this theory, identify three strategies that organizations use to manage conflicting objectives in innovation processes (such as design and efficiency), through a study of the Italian company Alessi:

- *Splicing*: This involves creating new connections between individuals involved in the innovation process who may have different objectives. For example, fostering collaboration between designers focused on high-design products and production staff focused on efficiency can create a shared understanding and a dynamic truce.
- *Activating*: This entails selectively emphasizing or de-emphasizing certain actions within the innovation process depending on the specific product goals. Giving more weight to the initial design phase for high-design products, and focusing on cost analysis for mass-market products, can help to navigate the conflict between standardization and flexibility.
- *Repressing*: This strategy involves, at times, circumventing formal procedures to allow for greater flexibility in either the design or production process. This could involve informal negotiations between departments, or temporary deviations from standard operating procedures to accommodate a particular project's needs.

While these strategies are not developed specifically for environmental sustainability tensions, they are useful for analyzing the performance-related conflicts (cost, quality, speed and sustainability) common in green innovation.

Focusing of corporate sustainability perspective two main strategies for addressing trade-offs emerge.

- The first one is the *win-win strategy*, which assumes that sustainability should only be pursued if it contributes to corporate profitability (*Román, 2022*) and companies do not perceive tensions as a problem because sustainable innovation leads always to financial gains (*Di Paola et al. (2021)*.

- The second one is the *avoidance strategy* or *trade-off approach*, which involves sacrificing one goal in favor of another and usually companies prioritize economic objectives over environmental and social ones. In some cases, this approach evolves into a paradoxical perspective, where companies continue to exploit existing products while developing new, more sustainable alternatives. (*Di Paola et al. (2021)*)-

Although these studies provide useful insights into how F&B companies manage tensions, they rarely focus explicitly on green innovation and often adopt a primarily instrumental perspective. Therefore, a more comprehensive understanding and classification of tensions and trade-offs specifically related to green innovation is needed.

2.3 Green Information Systems and environmental data analysis

In the transition toward more sustainable business models, the ability to collect, process, and interpret environmental data has become a key enabler of green innovation. Within this context, Green Information Systems (Green IS) play a crucial role by supporting organizations in tracking, analysing, and improving their environmental performance. This is particularly relevant in the F&B sector, where complex supply chains, resource-intensive operations, and increasing regulatory and consumer pressures demand more transparent and data-driven sustainability practices.

This chapter explores the concept of Green IS and their role in supporting green initiatives and promoting innovation. It begins by defining Green IS and outlining their practical applications in sustainability management, including emissions tracking, resource optimization, and reporting. The chapter then discusses how Green IS can drive green innovation by enhancing collaboration, improving customer orientation, and managing internal and external data. Drawing on Information Processing Theory (IPT), it highlights how data systems can reduce uncertainty in innovation processes. Finally, the chapter addresses how Green IS can help organizations manage tensions and trade-offs inherent in sustainability-oriented innovation, particularly by enabling better-informed decision-making.

2.3.1 Overview of Green Information Systems

More broadly, an Information System (IS) is defined as a combination of people, processes, and technologies that enables the processing of digitized information. Green Information Systems (Green IS), on the other hand, refer to IS-enabled organizational practices and processes designed to improve environmental and economic performance (*Melville, 2010*). More specifically, a Green IS can be considered as practical tools that support environmental management activities, such as carbon footprint analysis, emission reduction, resource optimization, cost savings across the supply chain for green SCM (*Ayala et al. 2020*).

An effective Green IS enables organization to track, analyse, and mitigate adverse environmental impacts from various business activities by actively monitoring energy usage, resource consumption and emissions. *(Carberry et al., 2019)*. Beyond environmental monitoring, Green IS can also help a company to promote sustainable activities, including setting up green plans, facilitating smooth communications between different functional departments, and improving operational efficiency and management capabilities (*Liu et al., 2018*). A prominent example of Green IS is represented by environmental management systems, which are structured programs that rely on information systems to monitor, evaluate, improve, and communicate environmental performance. These systems typically manage data related to both inputs (e.g., energy, water, materials) and outputs (e.g., waste, emissions), establishing critical baselines for performance evaluation. In summary, the three environmental sustainability core dimensions that a Green IS can address are: resource efficiency, by optimizing the use of resources to minimize waste and maximize output, waste control, by reducing and managing waste through better processes and technologies, emission reduction, by lowering emissions of pollutants and greenhouse gases *(Kocoglu et al. 2025*)

There are several reasons why companies implement such a tool into their processes. One of the most prominent is the need to comply with sustainability reporting obligations. In fact, the rise of sustainability reporting obligations has created incentives for firms to develop internal systems capable of tracking and reporting environmental performance. The rise of standardized reporting frameworks, such as the Global Reporting Directive (GRI) and Carbon Disclosure Project (CDP), has facilitated the development of commercial software packages to support the systematic collection, processing and disclosure of environmental data (*Carberry et al. 2019)*. Another critical motivation Organizations need reliable environmental data to understand the causes and effects of their environmental impact, assess the effectiveness of sustainability initiatives, and inform decision-making (*Melville, 2010*). Many studies, in fact, highlight that measuring product’s environmental impact or performance which is rather a complex process and companies needs to be supported in facing this challenge (*Dangelico and Pjuari, 2010*).

According to *Chen et al (2011),* Green IS practices can be grouped into three categories. The first focuses on *pollution prevention* and involves the use of information systems, such as enterprise carbon and energy management systems, to reduce pollution generated by business operations. The second category centres on *product stewardship*, referring to innovations in the use of digital platforms and communication or collaboration systems that enhance the environmental sustainability of both upstream and downstream supply chains. The third category relates to *sustainable development* and encompasses innovations that use information systems for broader organizational transformation, such as sustainable product development and knowledge or learning management systems (*Ijab et al 2012)*.

An increasing number of studies that examine the role of IS for environmental sustainability have appeared in response to the environmental challenge. These studies fall in two categories: abstract (investigate factors that influence the adoption of any type of Green IS) and substantive (conceptualize requirements for some type of Green IS, such as energy systems or examine particular systems for specific environmental challenges, such as energy consumption, greenhouse gas emissions or organizational initiatives) (*Loasen et al. 2017*).

Another categorization of Green IS is the one between strategic and operational Green IS. Strategic Green IS include the carbon management systems and refer to the Green IS that aims at greening business processes (*Butler, 2011*). The second kind, instead, is operational and aims at educating employees about sustainable choices and behaviours have gained increasing attention (*El Idrissi and Corbett, 2016)*.

2.3.2 The role of Green Information Systems in promoting green initiatives

Green IS can improve environmental capabilities and reduce the environmental impact in several ways as represented in Table 4. First, Green IS can **enhance resource efficiency** by optimizing IT infrastructure and organization-wide business processes, leading to both environmental and economic benefit (*Hanelt et al., 2011*). Additionally, through big data analysis, Green IS support **hotspot identification**, enabling companies to pinpoint areas of excessive energy use and implement corrective actions. These may include process optimizations, replacing inefficient equipment, balancing load distribution, and reducing power consumption during peak periods (*Yu and Chen, 2023*). Such capabilities offer not only operational improvements but also provide strategic value by uncovering knowledge gaps in processes, strategies, and products (*Butler, 2011; Helo et al., 2024*). In doing so, they support the development of new capabilities that facilitate environmentally responsible **decision-making** (*Looeser et al. 2017*).

Additionally, Green IS contribute to **improving a firm's reputation** by supporting the development of environmentally friendly products, strengthening brand image, and providing tools for environmental performance tracking and reporting. IS-based environmental management systems can facilitate the monitoring of and reporting about the corporate environmental footprint to internal and external stakeholders, elevating the firm's reputation (*Loeser et al., 2017*). Moreover, Green IS foster **supplier integration** and **customer orientation**: by leveraging IS to monitor resource use and assess environmental impacts throughout the product lifecycle, companies can better align with environmental standards and market expectations (*Loeser et al., 2017*). Within organizations, Green IS **enhance collaboration** by offering transparent, streamlined communication platforms that increase trust and improve information sharing among stakeholders, including investors, suppliers, and consumers (*Yu and Chen, 2023*). By providing a platform, collaboration and smooth communication among various functional units is enhanced, both within the company and between the company and its suppliers and customers (Ayala et al. 2020).

BENEFITS OF GREEN IS IMPLEMENTATION	
HOTSPOT IDENTIFICATION	Green IS help detect high-impact areas (e.g., energy waste) through data analysis, enabling targeted improvements
DECISION-MAKING	By uncovering process and product inefficiencies, Green IS support informed and environmentally responsible decisions.
IMPROVING A FIRM'S REPUTATION	Green IS boost brand image by enabling transparency in environmental tracking and reporting.
SUPPLIER INTEGRATION	Green IS allow firms to share data with suppliers, monitor environmental inputs, and collaborate to reduce impact across the supply chain.
CUSTOMER ORIENTATION	Green IS help firms understand and respond to customer expectations by providing transparency, traceability, and data on environmental performance.
INTERNAL COLLABORATION	Green IS foster trust and coordination by enabling clear, transparent communication among actors inside the company.

Table 4: Benefits of green IS implementation
Source; author's elaboration

These categories can be classified into three classes of technology affordances that Kocoglu et al. (2025) identify:

- *Impact Assessment*: This involves using digital tools such as sensors, data analytics, and monitoring systems to evaluate the environmental impact of organizational activities. These tools help identify inefficiencies in resource usage, track emissions, and measure waste generation.
- *Informed Collective Formation*: Digital technologies facilitate collaboration and knowledge sharing among stakeholders (e.g., employees, suppliers, communities). Platforms like cloud computing or social media enable organizations to share sustainability-related data, coordinate

efforts across departments or supply chains, and engage external stakeholders in eco-friendly initiatives.

- *Behavioral Modification*: Technologies can be used to influence and change behaviors toward more sustainable practices. For instance, gamification apps or real-time feedback systems encourage employees or consumers to adopt energy-saving habits or reduce waste.

2.3.3 Role of Green IS in promoting green innovation

The implementation of Green Information Systems (Green IS) influences not only green initiatives broadly but also innovation processes aimed at developing products and processes with reduced environmental impact. Although some studies have proposed categories through which Green IS can support green innovation (*Ayala et al. 2020*, *Qu and Lu, 2022*), a comprehensive framework is still lacking.

Much of the literature focuses on two main mechanisms: enhanced collaboration and customer orientation. *Ayala et al. (2020)* explain how an effective Green IS can significantly enhance a company's information processing capacity by providing a platform that facilitates collaboration and communication across various functional units. By being able to share information with their stakeholders, companies are able to minimize information asymmetry and foster stronger collaborations that drive green innovation (*Qu and Lu, 2022*). The integration of suppliers is also fundamental because it enables companies to develop and introduce products into new markets more rapidly (*Ayala et al. 2020*). Supplier integration refers to the process of establishing close collaborations with key suppliers to jointly address business challenges and optimize processes. By fostering stronger ties with suppliers, companies can reduce uncertainties and risks, accelerate product development, and facilitate market entry.

Customer orientation is another critical enabler of green innovation. This dynamic approach requires companies to continuously monitor and respond to customer needs, especially those related to environmental values. To maintain a high level of customer orientation, firms must actively gather and analyse data related to consumer preferences, particularly regarding environmental concerns. Companies that prioritize consumer engagement must focus on effective communication and efficient information processing to meet specific customer needs. A strong customer-oriented approach enhances a company's ability to process information, thereby reducing uncertainties associated with green innovations and improving overall decision-making (*Qu and Lu, 2022*).

More in general, green innovation processes are facilitated by the higher amount of information that Green Information Systems are able to provide: information exchange and knowledge sharing are in fact, able to reinforce innovation efforts (*Qu and Lu, 2022*). Managing large volumes of data is especially important in the context of green innovation, which is often challenged by external uncertainties such as technological disruption, market fluctuations, and regulatory changes (*Ayala et al. 2020)*. To navigate these complexities, companies need a robust Green IS capable of supporting high-level decision-making.

The importance of the analysis of data during the innovation processes can also be understood through the lens of *Information Processing Theory (IPT),* which emphasizes the importance of managing organizational complexity through improved information processing. According to IPT, expanding a firm's information-processing capacity helps mitigate uncertainty and enhances innovation performance. A well-developed Green IS, therefore, supports communication and coordination both internally and along the supply chain. By facilitating supplier integration and customer responsiveness, Green IS enhancing a firm's capacity for sustainable innovation in both products and processes.

However, a key limitation of current research lies in its narrow focus on supplier and customer relationships, often overlooking other potential ways in which Green Information Systems (Green IS) can support innovation. As noted by *Ayala et al. (2020)* there is also limited understanding of the specific features that define an effective Green IS for facilitating green supply chain integration and enhancing information-processing capacity. Furthermore, despite the central role that data plays in innovation processes, particularly those aimed at reducing environmental impact, there is a lack of comprehensive insight into how information analysis contributes to these processes when viewed through the lens of Information Processing Theory.

In the specific context of food innovation, data plays a fundamental role. *Frau et al. 2024* highlight how digital data sources are essential tools for understanding innovation strategies in the agri-food sector. The paper distinguishes between internal and external data. Internal data originates within the organization and includes granular operational metrics such as sensor-generated production statistics, equipment performance logs, and quality control records. These datasets offer real-time insights into production efficiency, resource use, and product consistency, enabling companies to refine existing processes and products. However, an excessive focus on internal data can lead to innovation myopia, over-optimizing current systems while neglecting market trends. For instance, a dairy company might optimize yogurt fermentation using temperature and bacterial culture data yet overlook the growing consumer demand for plant-based alternatives indicated by external market reports. External data, on the other hand, comes from outside the organization and includes market trend analyses, competitor benchmarking, consumer sentiment from social media, and inputs from supply chain partners. This type of data provides a broader perspective on evolving consumer preferences, regulatory changes, and disruptive market dynamics. It often acts as a catalyst for radical innovation by revealing unmet needs and emerging opportunities. Although the paper does not focus exclusively on environmental data, it emphasizes that expanding the information base, by integrating both internal and external sources, is essential for fostering innovation in food companies. Despite the extensive research on the importance of data in supporting green initiatives, limited attention has been given to the food sector. While some studies have started to explore sustainability within the food industry, there is still a significant gap in understanding how Green IS are implemented in F&B companies.

2.4 Research gap and definition of research questions

Following the literature review, several gaps and opportunities for further investigation emerged. These insights have been distilled into the following three research questions:

1. *What are the drivers that motivate food and beverage companies to implement Green IS?*

Despite the growing academic interest in Green IS, there is a notable lack of research examining why companies adopt Green IS and more specifically in the F&B sector. This industry has unique characteristics and environmental challenges, yet the literature often treats it as a homogeneous category. Understanding the specific drivers is essential for Green IS providers to better align platform functionalities with the actual needs of companies in this sector. This gap also opens the door for future research to assess whether current Green IS platforms effectively address these needs.

2. *To what extent can Green IS enable green innovations?*

While the literature discusses Green IS extensively, it often lacks a targeted focus on its role in enabling green innovation. Much of the existing research emphasizes collaboration along the supply chain but overlooks other key functionalities that may foster innovation. This research aims to bridge this gap by exploring how Green IS can support broader innovation strategies beyond supply chain collaboration.

3. *Can Green IS address the challenges that characterize green innovation processes?*

There is currently limited exploration of the relationship between Green IS functionalities and the challenges they are intended to resolve. This study seeks to clarify the mechanisms through which Green IS can alleviate tensions inherent to green innovation. To address this research question, two sub-questions are introduced:

3.1 *What are the challenges that arise in green innovation processes in the F&B sector?* Although existing studies have identified various tensions in green innovation, a sector-specific analysis is necessary to understand how these tensions manifest uniquely in the F&B industry.

3.2 *What are the resolution mechanisms enabled by Green IS to address green innovation challenges?*
This question investigates how specific features of Green IS can contribute to mitigating the challenges and trade-offs associated with green innovation efforts.

3. Methodology

3.1 Research approach

To address the research questions outlined in the previous chapter, this thesis employs a qualitative research approach, drawing on both primary and secondary data. The choice of a qualitative method is justified by the exploratory nature of the research, which investigates a relatively novel phenomenon (*Sofaer 1999*). In such cases, quantitative methods based on a multiple case study are often inadequate due to the lack of existing structured data and theoretical models (*Eisenhardt 1989*). So, qualitative methods seem to be well-suited for studying complex and context-dependent phenomena such as Information Systems (*Lee and Liebenau 1997*) and, in particular, the way they are used to support green innovation in the F&B sector.

Primary data were collected through semi-structured interviews with two key stakeholder groups: 1) companies that develop and provide Green IS solutions, and 2) F&B companies that implement and use these technologies. The decision to include both perspectives, technology providers and end-users, was made to capture the dynamic interaction between those who design Green IS and those who apply them in practice. This dual perspective is essential to gain a comprehensive understanding of how Green IS can effectively support green innovation. Insights from practitioners with direct experience added depth and real-world context to the analysis**.**

Secondary data consisted of publicly available information retrieved from the official websites and digital communication channels of Green IS platforms. These sources provided a foundational understanding of the platforms' functionalities, technical characteristics, and unique features, which supported both the interpretation of interview findings and the overall analysis. This step was essential to gain insights into the digital solutions currently available in the sector and to understand how Green Information Systems are used by companies in the F&B industry. These digital solutions are generally structured as platforms that offer a comprehensive view of a company's environmental impact, particularly with regard to emissions along the supply chain. They combine primary environmental data, when available, with secondary data that, although less precise, serve as valuable estimates. This is particularly important for Scope 3 emissions, where direct data is often unavailable, and approximations are necessary to assess the environmental footprint of food products. In addition to emissions tracking, these platforms often include other functionalities. Some of them support sustainability reporting by generating reports automatically or by providing guidance to help companies meet regulatory requirements and voluntary sustainability standards. A clear understanding of how these platforms function and the main services they offer is essential for interpreting the perspective of food companies that adopt them and for evaluating their impact on innovation processes.

3.2 Case selection

The F&B sector was selected because it is one of the most environmentally impactful industries, contributing significantly to global greenhouse gas emissions, resource consumption and waste generation. At the same time, it plays a central role in people's daily lives and offers considerable potential for innovation towards environmental sustainability. This thesis focuses primarily on companies based in UK and Italy, two countries with strong traditions and global reputations in the food sector, both in terms of production and innovation. Their mature food industries make them valuable contexts for studying how sustainability practices are being integrated into corporate processes.

The selection of the F&B companies for the interviews was guided by the aim of identifying firms that are at the forefront of sustainability initiatives, those that have already introduced, or are actively developing, low environmental impact or innovative products. Participants were identified through multiple channels, including attendance to sustainability or innovation-related conferences such as the Open Innovation Forum and the Agri-Food Supply Chain Resilience conference, both organized by the Institute for Manufacturing at the University of Cambridge, as well as through direct outreach via company websites and LinkedIn. In some cases, the sampling followed a snowballing strategy (*Naderifarì and Ghaljaie 2017*), where initial interviewees recommended other relevant contacts within their networks. The individuals interviewed all work in food and beverage companies, specifically in roles related to sustainability and/or research and development (R&D) activities. The name of the companies has been anonymized due to data protection reasons (Table 5).

	Company Alfa	Company Beta	Comapany Gamma	Company Delta
Based in:	Italy	UK	Italy	Italy
N° of employees	>10k	>10k	1K-5k	5k-10k
Role of the people interviewed	Innovation Manager	Sustainable Nutrition Senior Manager	Plant environmental manager	Global RDQ Capabilities Vice President.
Business focus	Collective catering and foodservice	Food solutions and ingredients	Production of ice cream and frozen bakery products	Production of pasta, sauces, bakery products and cereals

Table 5: Profile of Interviewed Food and Beverage Companies

The selection of Green IS providers was based on their specialization and expertise in the F&B industries. Platforms were identified through web and LinkedIn searches, discussions with food industry stakeholders, and a review of sustainability reports and company websites. From the platforms identified, six were initially selected as they best represent Green Information Systems tailored to the specific needs of the F&B sector. Of these six, only four agreed to participate in the study and to conduct an interview. The names of the companies, along with additional information including the roles of the individuals interviewed, are reported in Table 6. In these cases, the companies granted permission for their names to be included. This assessment was informed both by feedback from food companies regarding the platforms they use and by publicly available information online.

	FOODSTEP	MYEMISSIONS	SUSTAINED	MONDRA
Based in:	UK	UK	UK	UK
N° of employees	11-50	11-50	2-10	51-200
Role of the people interviewed	Go to Market Leader	Head of Client Success	Chief Scientific Officer	Head of product & product manager
Web-site	https://www.foodsteps.earth	https://myemissions.com	https://sustained.com	https://www.mondra.com

Table 6: Profile of Interviewed Green IS Providers Companies

3.3 Data collection

The interviews were conducted online and recorded, following a semi-structured format. Two sets of pre-determined questions were prepared and remained the same for every interview: one for platform providers and another for F&B companies. The questions were shared in advance and used as a guide to structure the discussion, while allowing flexibility for open-ended dialogue. The interviews took place between March and May 2025, and lasted between 30 minutes and one hour. The interviews were conducted in English or Italian, depending on the nationality of the interviewee, and they were later all translated in English and analysed in English to maintain consistency. The participants interviewed held roles in the areas of sustainability or R&D, and innovation. To gain deeper insights, the critical incident technique (*FitzGerald et al. 2008*) was applied, with interviewees encouraged to provide concrete examples to illustrate their points. This helped to clarify how green innovation is implemented in practice and how digital tools are applied within different organizational contexts.

3.4 Data Analysis

A thematic analysis was conducted: the data collected through the interviews were analysed using a structured, iterative approach inspired by *Eisenhardt (1989)*. The process began with the transcription of the interviews, followed by the translation of those conducted in Italian. The next phase involved open coding of the transcripts, aimed at identifying recurring concepts grounded in the language used by the participants.

These emergent concepts were then examined, grouped, and categorized to form initial themes. Each transcript was subsequently re-read to verify the consistency of the preliminary findings and to refine the analysis in light of the emerging classifications. This iterative process ensured that the coding remained both systematic and sensitive to the nuances of participant input.

This analytical strategy enabled the development of a well-founded and in-depth understanding of how Green Information Systems (Green IS) contribute to promoting green innovation in the F&B sector.

4. Empirical research and findings

4.1 Overview of Green IS for the food and beverage sector

The objective of this section is to provide an overview of the most relevant Green IS solutions that are specifically tailored for the food and beverage sector. While many existing platforms serve a wide number of different industries, the focus here is on those with a clear specialization and demonstrated expertise in the F&B domain. This analysis is essential because, although the academic literature discusses green IS in general terms, it often lacks concrete insights into how these platforms actually function in practice. Furthermore, the analysis does not aim to provide a technical comparison of all tools that are currently available, but rather to highlight how these systems support sustainability efforts through the description of their main features and characteristics. The overview also represents a foundation for the next section, in which empirical insights gathered through interviews with both platform providers and F&B companies will be presented.

Most of the platforms examined in my analysis are offered by start-ups or relatively young enterprises, reflecting the fact that the need to track emissions has emerged only in recent years. The main information about the companies analysed is presented in the Table 7 below.

	FOODSTEP	MYEMISSIONS	CARBONCLOUD	HOWGOOD	SUSTAINED	MONDRA
Based in:	UK	UK	SWEDEN	US	UK	UK
Year of fundation	2019	2021	2019	2007	2021	2020
Reporting level (product or business)	Product and business	2 different tools for product and company footprint	Product and business	Product and business	Product and portfolio i.e. report at individual product level, and at volume i.e. for the entire manufactured range	Product
Alignment on international carbon footprint reporting	LCAs are aligned with the ISO 14040 Standard, and follow the GHG Protocol Life Cycle Accounting and Reporting Standard. Guidance from WRAP and SBTi and Iso are also followed.	For company GHG assessments, reports align with the GHG Protocol Corporate Standard and follow guidance from Wrap and SBTi. For product GHG assessments, align with GHG Protocol, Product Life Cycle Accounting and Reporting Standard	Align with ISO 14067 and GHG protocol Product Life Cycle Accounting and Reporting Standard	GHG accounting is in accordance with the GHG Protocol Product Life Cycle Accounting and Reporting Standard, GHG Protocol Corporate Standard, and IPCC GWP100a 201	Aligned to ISO14040, GHG Protocol and EU's PEF	Mondra's underlying data structure enables ultimate flexibility to meet both the reporting needs of today (SBT/FLAG, TCFD, CMA/ASA, GHG Protocol) and the compliance requirements of tomorrow
Inclusion of other sustainability criteria	GHGs, land use, water use	None. Focus is only on carbon measurement	Metrics Beyond Carbon: blue water usage, biodiversity impact and labor risk	Metrics beyond greenhouse gas emissions include: blue water usage, soil health, biodiversity, deforestation, land occupation, labor risk, and animal welfare.	EU's PEF covers 16 environmental indicators including water, land use, soil toxicity etc.	Eutrophication, Land Use, Biodiversity, and Water Usage (scarcity weighted)
Allocation rules	Primarly economic allocation	Flexible	Economic	Flexible	preference for phisical allocation	Economic
API integration	working on it	Yes	Yes	Yes	Yes	Yes
Supplier integration solution	yes	integrate with procurement software, like ProcureWizard.	Yes	Not specified	Yes	Yes
Web-site	https://www.foodsteps.earth	https://myemissions.com	https://carboncloud.com	https://www.howgood.com	https://sustained.com	https://www.mondra.com

Table 7: Platform Overview
Source: Author's elaboration on the basis of web-sites information

As shown in Table 7, there are several distinguishing characteristics among the various companies. First, most of these platforms can calculate and report the carbon footprint at both the product level and the company-wide level. Furthermore, they often go beyond a single sustainability criterion (typically carbon footprint) and provide assessments for other environmental indicators, such as land use, water use, eutrophication, and acidification. A key difference lies in the methodologies which are used to provide services to client companies. In fact, some platforms clearly outline their methodological approaches on their websites, including details such as the type of allocation applied. Others, however, do not provide specific methodological information, though all of them declare alignment with recognized standards such as ISO norms or the GHG Protocol. As explained in the following sections, other differences include features such as API integration. APIs allow environmental platforms to connect with other management systems, and functionalities that enable suppliers to access the platform to share information or collaborate in the innovation process.

The empirical analysis of these platforms, realized on the basis of secondary data, revealed that they share a common structure: their services are generally structured around four core activities: **Calculate, Reduce, Communicate, and Report**. These four pillars have therefore been used as the framework for the following subsections, which describe the main functionalities and key features of each platform.

STEP 1: Calculate

STEP 2: Reduce

STEP 3: Communicate (Labelling and impact assessment)

STEP 4: Report

STEP 1: Calculate

This activity regards emissions calculation, and for this task platforms do differ to a certain extent, primarily in the methodology and the databases they use.

Specifically, most platforms state on their websites that the carbon footprint of food products is calculated in accordance with ISO 14067 and the GHG Protocol Product Life Cycle Accounting and Reporting Standard. The term "life cycle" is meant to represent the environmental impact across the life of a product. However, since the final destination for the food is often the sewage system, the platforms often consider the impact from the cradle (where/when the food comes out the earth) to the gate (often the grocery store shelf). In allocating the impact in LCA, different allocation methods exist which can allocate specific environmental impact to the process' multiple outputs. The most commonly used method used by these platforms is to distribute impact based on measurable properties like mass or volume. This approach is preferred by standards such as ISO 14044 and the EU Product Environmental Footprint because it ensures transparency, consistency, and replicability. The other allocation method is the Economic allocation method, which assigns impacts based on market value, although it is less commonly used. In fact, while it may reflect demand, it introduces challenges like price variability, lack of data, and potential biases. Therefore, economic allocation is generally applied only when physical measures are not meaningful or available.

For the calculation of indirect emissions (Scope 3 emissions), platforms typically adopt one of two approaches: the volume-based method and the spend-based method. The *volume-based* method relies on physical quantities of purchased goods (e.g., kilograms of raw materials), which are multiplied by specific emission factors (e.g., kg CO_2e per kg of beef, grain, or milk). This method is generally more accurate, as it is based on concrete, product-specific data, but it requires a level of detail that is not always available across the entire supply chain. In contrast, the *spend-based* method relies on the monetary value spent on each product or service category, applying an emission factor expressed per unit of currency (e.g., kg CO_2e per euro spent). While easier to apply, since financial data are typically more accessible, this method is less precise, as it does not account for qualitative differences between products (e.g., organic versus conventional meat). In practice, many companies begin with a preliminary estimate using the spend-based method, and later refine their assessments with a volume-based approach, especially for high-impact categories. The choice between methods depends on data availability and the level of granularity required for reporting or strategic analysis. Some platforms explicitly state the methodology they use. For instance, Foodsteps relies on a volume-based approach, stating: *"Taking a spend-based approach is risky, as your calculations and baseline can change based on price fluctuations."*

Another point of differentiation is the type of data and databases used. In fact, most platforms combine primary data, directly collected from operations or suppliers, with secondary data obtained from databases and published studies. Primary data consist in process activity data (i.e. physical measures of a process that result in GHG emissions or removals, direct monitoring, stoichiometry, mass balance, or similar methods from a specific site), or data that is averaged across all sites that contain a specific process. Primary data can also be obtained directly from suppliers. In fact, some platforms offer supplier engagement solutions that help companies collect relevant environmental information from their supply chain partners. Secondary data, on the other hand, can come from external sources (e.g., lifecycle databases, industry associations, etc.) or can be data from another process or activity in the supplier control that is used as a proxy for the process. These data can be adapted to the process or can be used "as-is". Examples of secondary data include, for example, the Foodsteps database, which consists of 3,000 individual studies, combining academic research, their own primary studies, and third-party supplier-specific LCAs from the industry. An example of core data sourced is the meta-analysis by Poore & Nemecek in 2018, which Foodstep has enriched with data from ongoing collaborations with academia and industry partners

Finally, while GHG emissions are the most common metrics calculated, some platforms also assess other environmental indicators, including land use, water use, eutrophication, and acidification, as it is possible to see from Foodstep's web site (Figure 10).

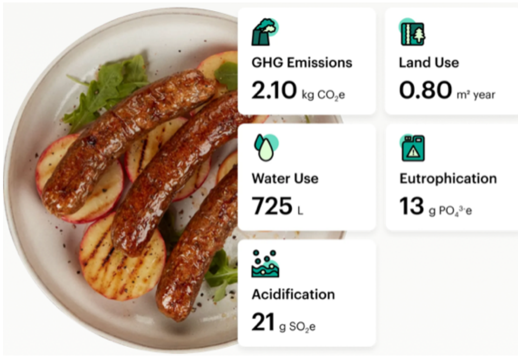

Figure 10: Environmental indicators available on a platform
Source: Foodstep website

STEP 2: Reducing

Most of the platforms support clients not only in calculating the emissions of their products but also in reducing their environmental impact. This support is typically offered through three main services: *hotspot identification*, *scenario modelling* and *tracking progress's tools*.

Hotspot identification, one of the most valuable functionalities offered by platforms, enables companies to identify which life cycle stages, ingredients, or suppliers contribute most to environmental impact. As cited in CarbonCloud's web-site: "*To achieve your reduction targets you need to identify hotspots and better sourcing alternatives. Our platform provides a detailed breakdown of categories that contribute to your emissions. The detailed data view makes it easy to identify the greatest contributors*". This insight helps businesses determine where to focus efforts to improve the sustainability of their products. As illustrated in Figure 11, platforms can highlight the life cycle phases that contribute most significantly to the overall environmental footprint. In the example of Figure 11, the processing phase accounts for the highest share of emissions (22%**)** in the production of *Cauliflower Bites*. Another case (Figure 12), highlights how the raw material phase is the primary contributor to environmental impact, particularly in meat-based products like the chicken hot pie in the example. Some platforms also offer the ability to identify which specific ingredient most contribute to the overall impact (as showed in Figure 13). This includes the option to compare the same ingredients sourced from different countries, offering a practical tool to suggest lower-impact alternatives and support more sustainable supply chain decisions.

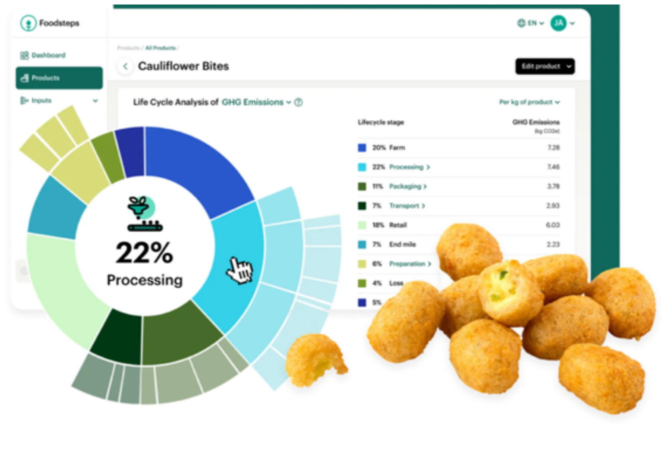

Figure 11: An example of GHG Emissions for each lifecycle stage
Source: Foodstep website

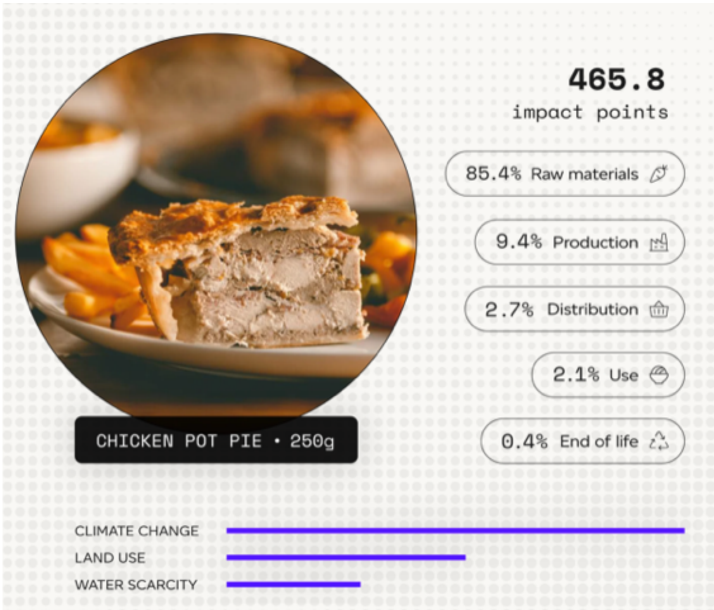

Figure 12: Example of environmental impact for each lifecycle stages (%)
Source: Sustained web-site

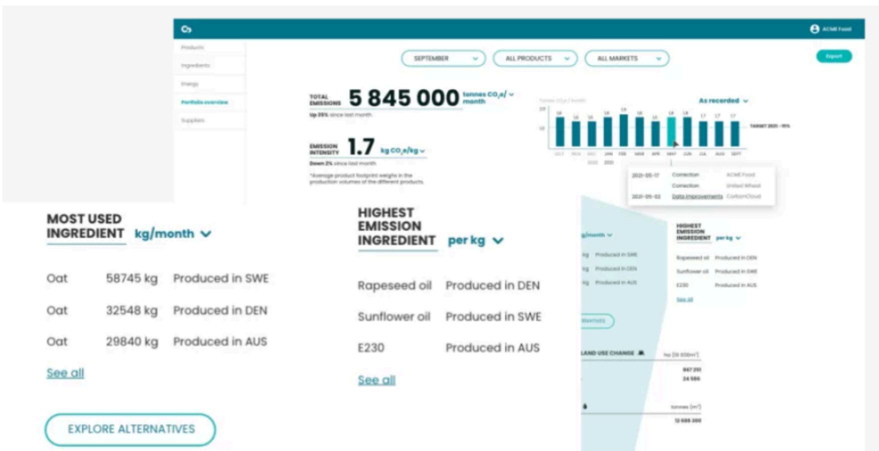

Figure 13: Example of hotspot identification
Source: CarbonCloud's web-site

As previously mentioned, the highest emissions are often associated with raw materials, making ingredient reformulation a common strategy for emission reduction. For this reason, a growing trend among F&B companies is to switch to alternative ingredients, adjust ingredient proportions, or source from different suppliers. In other cases, changes in packaging or processing methods can also result in meaningful emission reductions. Although the impact of these changes may be smaller, they are sometimes preferred due to their lower implementation costs.

To facilitate these decisions, many platforms also offer *scenario modelling* and product comparison tools. As reported in HowGood's web-site: "*Our interactive scenario planning tool allows you to view "in real time" the impact of changing sourcing locations, ingredient swaps, supplier interventions, and other abatement levers*". These functionalities enable companies to simulate and compare various options, such as different sourcing strategies or transport routes, before implementation. This helps in identifying the most effective strategies to reduce environmental impact while maintaining product quality and performance. As shown in Figure 14 from the platform Mondra, it is possible to vary different change factors like site, sourcing, composition and packaging in order to find the solution with the lower environmental impact.

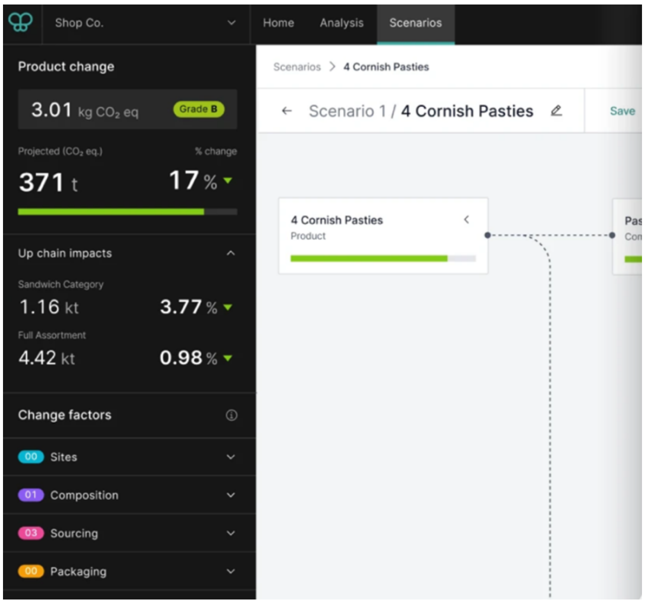

Figure 14: Example of scenario modelling functionality
Source: Mondra's web-site

The final key feature in the reduction phase, offered by some platforms, is the ability to *track progress* over time. Most platforms provide tools that monitor each improvement and visualize the gradual reduction of emissions. This functionality enables companies to assess their progress relative to the initial baseline and offers a clear overview of the environmental benefits achieved through specific actions. It also supports ongoing evaluation of progress toward defined sustainability goals. An example of this is illustrated in the graph provided by HowGood in Figure 15.

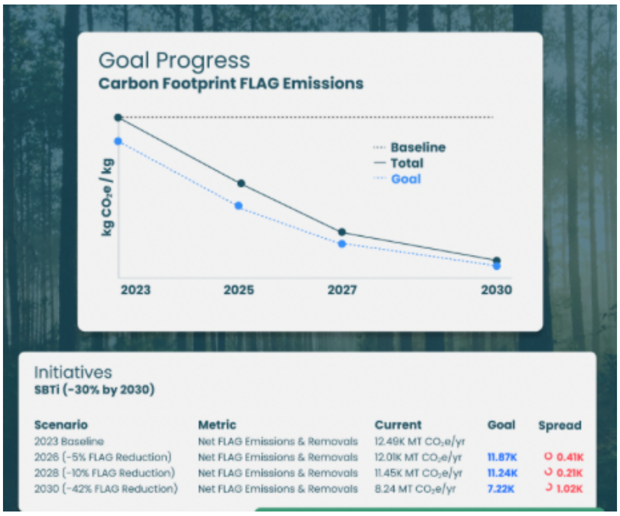

Figure 15: Example of tracking environmental reduction progress
Source: HowGood's website

Tracking progress serves both internal and external purposes: internally, it enables teams to measure the effectiveness of their strategies; externally, it offers credible data to communicate achievements to stakeholders and demonstrate a company's commitment to sustainability.

For instance, as illustrated in Figure 16**,** the platform allows for a direct comparison between the environmental impact of the original beef burger and a reformulated plant-based alternative, clearly showing the reduction in emissions and other impact indicators.

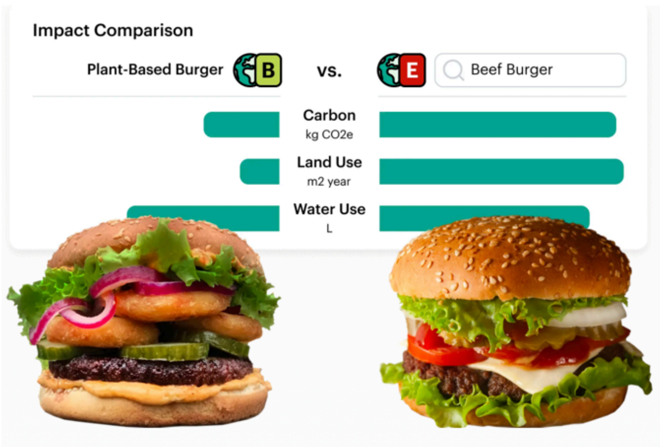

Figure 16: Example of product impact comparison functionality
Source: Foodstep web-site

An important aspect of this step is the ability of platforms to integrate with existing management systems used by companies during the R&D phase. This integration enables R&D teams to embed environmental considerations directly into their innovation processes. For example, My Emissions has partnered with Point74, a product lifecycle software provider, to ensure that carbon assessments are automatically incorporated into the company's product development workflow.

STEP 3: Communicate

An essential motivation for companies adopting Green IS tools is the opportunity to effectively communicate their sustainability efforts. With regard to this issue, platforms often include features that automatically generate impact statements, which can then be shared with customers, partners and regulators to provide transparent and verifiable information on environmental performance.

Among the most visible tools available for communication is carbon labelling. These labels allow companies to display the carbon footprint of a product directly on packaging or menus, thereby empowering consumers to make more informed choices. For instance, My Emissions offers a simplified A-E carbon label, paired with traffic light colours to provide an intuitive visual representation of the product's environmental impact. Labels can be customized in terms of granularity and design, depending on the needs and communication strategy of the company.

However, communication is not limited to the end consumers. Engaging the entire supply chain is equally important. Platforms like Mondra provide supplier engagement tools that promote collaboration and transparency across all stages of production. These platforms encourage suppliers to take ownership of their environmental impact and offer functionalities such as real-time data sharing, integration of primary farm-level data, and support for collaborative product development. In such dynamic systems, as one actor improves its performance, the emission data for downstream partners is automatically updated. This interconnected structure represents a step-change in how sustainability is managed across supply chains.

By adopting integrated communication and data-sharing systems, companies are better equipped to demonstrate their commitment, share best practices, and access accurate primary data directly from suppliers, thereby enhancing both internal alignment and external accountability.

STEP 4: Report

A final key functionality of the analysed platforms is their ability to support companies in complying with both mandatory and voluntary disclosure requirements. In this field, Green Information Systems are increasingly designed to meet the growing demand for external compliance and sustainability reporting, such as those required by FLAG (Forest, Land and Agriculture), SBTi (Science Based

Targets initiative), and the Corporate Sustainability Reporting Directive (CSRD). These systems aim to provide affordable, accurate, and standardized data to facilitate compliance.

One of the most common forms of aggregated data produced by these platforms is the Life Cycle Assessment (LCA), which is typically aligned with ISO 14040 and follows the GHG Protocol Life Cycle Accounting and Reporting Standard. In many cases, LCAs are automatically generated with the support of artificial intelligence, allowing for greater scalability and efficiency in environmental reporting.

Another key output, which is increasingly requested by companies, is a comprehensive Scope 1, 2, and 3 emissions report, particularly important for organizations that have made public commitments toward net-zero targets. These reports help monitor progress and communicate achievements to external stakeholders. In this case, the focus is not on the single product; rather, the aim is to calculate the total emissions that the company is producing. For instance, My Emission offers a dedicated product for company-wide carbon tracking. This feature is gaining popularity, as reporting company-wide emissions will soon become a mandatory requirement for obtaining B Corp certification, whereas previously, it was only an optional criterion for earning additional points.

This analysis identified six key functionalities that characterize the environmental platforms examined and that play a crucial role in supporting innovation processes within F&B companies that are summarized in Table 8.

The first functionality relates to **supplier engagement**. Several platforms offer tools to involve suppliers directly, enabling data sharing across the supply chain and integrating primary data collected at farm or ingredient level. This creates a dynamic system where sustainability improvements by one actor are automatically reflected downstream, fostering transparency and collaboration across the production network.

A second important feature is the **integration with internal platforms and management systems**, such as those used during the R&D phase. For instance, partnerships between environmental platforms and product lifecycle software providers ensure that sustainability data—like carbon assessments—are embedded into the product development workflow. This integration allows R&D teams to consider environmental impacts from the early stages of innovation.

The third core functionality is the **ability to perform environmental data calculations**, particularly for emissions. Most platforms calculate carbon footprints in line with ISO 14067 and the GHG Protocol, considering life cycle stages from cradle to gate. Calculations often rely on a mix of primary and secondary data and can extend beyond GHG emissions to include indicators such as land use, water use, eutrophication, and acidification.

Another widely used function is **hotspot identification**, which allows companies to pinpoint the ingredients, suppliers, or stages of the product life cycle that contribute most to the overall environmental impact. This helps prioritize interventions where they can be most effective, such as reformulating recipes or switching sourcing strategies.

Finally, platforms often offer **scenario analysis** tools that allow companies to model and compare the impact of different sourcing or production decisions in real time. These simulations help evaluate potential strategies before implementation and are particularly useful for designing more sustainable products.

PLATFORM FUNCTIONALITIES	
Supplier integration functionaly	Able to collect and update supplier-specific data and promote collaborative sustainability.
Integration with other management systems	Embeds sustainability data into existing company tools, especially receipe management systems.
Environmental data calculations	Computes GHG emissions and other indicators using standard methodologies and databases.
Identification of hotspots	Detects the most impactful stages, ingredients, or suppliers in a product's life cycle.
Scenario analysis	Simulates and compares the environmental impact of different design or sourcing options.

Table 8: Environmental platform functionalities for innovation processes
Source: author's elaboration

4.2 Findings from the empirical research and discussion

Analysing the main Green Information Systems (Green IS) used in the F&B industry, along with their key characteristics and functionalities, was a crucial step in building a general understanding of what implementing a Green IS entails for companies in this sector. The analysis includes both interviews with both experts from the F&B sector and professionals from companies that develop environmental platforms. The decision to incorporate both perspectives was made to ensure a more comprehensive understanding of the topic. By considering the viewpoints of both users and providers of Green IS platforms, the analysis can uncover valuable insights into how these systems are developed, implemented, and perceived in practice.

With this foundation established, the analysis now turns back to the research questions, using insights from the interviews to explore each question in greater depth:

1. What are the drivers that motivate food and beverage companies to implement Green IS?

2. To what extent can green IS enable green innovations?

3. Can Green IS address the challenges that characterize green innovation processes?

- What are the challenges that arise in green innovation processes in the food sector?

- What are the resolution mechanisms enabled by Green IS to address green innovation challenges?

4.2.1 Drivers for the adoption of Green IS in the F&B Sector

In order to answer to the research questions the chapter is structured into three main sections. The first section explores the underlying motivations that drive food companies in their decisions to adopt Green Information Systems (Green IS). The second section investigates how green innovation is promoted through the use of these platforms. Particular attention is paid to the features of Green IS that support innovation, as well as the broader trends observed in the sector regarding sustainability-oriented technological adoption. The third section focuses on the key challenges and limitations that F&B companies encounter in pursuing green innovation. Additionally, the section highlights the connections between these challenges and the specific mechanisms through which Green IS can help to overcome them. The findings from the interviews are critically examined and contextualized through a comparison with insights from the existing literature. This comparison allows for a deeper understanding of how the empirical evidence aligns with, extends, or challenges established theories and prior research.

To answer to the first research question, the motivations for using Green Information Systems in the food sector were identified through interviews with both platforms providers and F&B companies, including those which are not currently using a specific platform but that have experience in the analysis of data and might adopt one in the future.

One of the main motivations is to improve **brand image**. For example, the service provider My Emission affirmed that "*adding the number (environmental information) next to them (plant-based products) help support and strengthen the messaging they want to communicate to consumers*.". Simarly, Foodstep, remarked: "*Some companies want to show a leadership position in environmental aspects and demonstrate how they're doing in those*". This is also the perspective from a F&B company such as Company Beta, "*we were able to show (our sustainability commitment), and we put a carbon claim on pack for those products in order to communicate to the consumers the benefits of the product*". What has emerged from our interviews is that companies are using Green Information Systems not only to communicate their environmental commitment to customers, but also to enhance their overall brand image.

Another common driver which has emerged from the interviews is the desire to communicate a company's environmental profile, but through structured and credible approaches, such as

standardardized methods of reporting or the formal declaration of emission reduction targets. For example, My Emission observed a growing interest among companies seeking support to obtain B Corp certification, particularly in response to updated requirements that now demand a comprehensive, company-wide environmental footprint assessment. As Sustained explained: *"B Corp requires businesses to be able to show that they're doing some kind of LCA and that they've got roadmaps and are taking action. That's exactly what our platform helps them achieve".* Similarly, the platform Mondra emphasized that an increasing number of F&B companies are making public commitments to achieve environmental targets. This trend has significantly increased the demand for reliable data and digital support: *"A focus on net zero targets with 2030 quickly approaching and voluntary reporting commitments, companies come to our platform for granular data to support that."*

Contrary to what is suggested in the existing literature, **regulation** has not yet emerged as a primary driver for tracking environmental data as Foodstep pointed out "*I think that in terms of regulatory compliance, in the UK context, we're probably still a couple of years away from regulation requiring companies to measure the environmental impact of their product in a robust way*." Sustained confirm this view, emphasizing that their platform is primarily design to support environmental impact rather than to serve as a compliance reporting tool: *"Compliance, from our perspective, is less of a driver. That's because, although there are regulations businesses need to follow, like the CSRD, we have not built a compliance reporting platform".* This suggests that, at present, most companies are not adopting environmental platforms due to direct legal obligations. Nevertheless, regulations are not seen as irrelevant. On the contrary, interviewees recognized its strong future potential. As Foodstep added: *"Once regulation is fully in place, it will be the main driver pushing most food businesses to engage seriously with these issues".* Company Delta also highlights the importance of regulation: *"We do these things also because the laws prescribe it. It's not just about timing, no. We do these things also because the laws prescribe it. When we started, it wasn't the main reason. But today, you know very well, the CSRD, etc., etc., everything that exists, obviously requires companies to do these kinds of things.".* This reflects a transitional moment: while regulation may not be the initial driver, it has now a significant influence on large companies, which are increasingly expected to report their sustainability efforts. Regulation is anticipated to play a central role in shaping industry behavior in the near future.

In other cases, companies use these platforms as a way to **differentiate themselves** from competitors. As My Emission explained "*working with a platform like ours is a way to stand out against their competitors*". Using the tools offered by Green IS companies are able to differentiate themselves against the companies in their same sector which are investing in green innovation in a different way.

Another key motivation, particularly relevant for wholesalers and manufactures, is the desire to gain a **business advantage especially during tenders**. Food manufactures, ingredient suppliers and even farmers are increasingly required to provide information on their carbon emission and green initiatives. This requirement is becoming a standard criterion during tenders. My Emission noted: "*if you're supplying fruit and veg into a big retailer, you're being asked whether you've done a company footprint. And same if you're like a wholesaler, or you sell to food service. It's the sort of thing that helps you win tenders, helps to basically stand out against your peers*". Sustained also confirmed the commercial relevance of sustainability performance in business-to-business context: "T*here's a commercial driver. And therefore they need a tool that helps them footprint their products and provide robust footprint data to their buyers."* This motivation is particularly strong in the food service sector, where public procurement plays a significant role. As highlighted by Company Alfa: *"The motivations are quite obvious, they stem from competitive pressure. As I mentioned earlier, most of our business comes from public tenders. In that context, they ask for circular economy projects, zero-kilometer products, organic goods, and socially impactful systems involving people with specific types of vulnerabilities."*

Furthermore, another motivation that emerged is the need for **assurance from a third party with expertise in environmental sustainability.** As Foodstep explained, "*they want the assurance of a third party who is an expert in sustainability to essentially make sure that they're doing it correctly*". In some cases, companies have already implemented environmental improvements and simply want to communicate their progress with greater credibility: "*simply want to communicate it with a bit more certainty in a way that it's understandable and, in a way, that also serve as a marketing tool*". Company Beta: "*if we want to talk credibly and externally about a product and its carbon footprint, HowGood gives us that level of assurance because it's a third party"*. In these cases the motivation lies in the fact that companies may lack the internal capabilities to precisely calculate the impact of their sustainability improvements. They seek the expertise of an external partner to verify that the changes they've made do, in fact, result in measurable environmental benefits. This third-party validation also helps increase their credibility with external stakeholders.

Finally, one of the core motivations driving companies to adopt environmental platforms is the **lack of internal expertise required to analyze and interpret sustainability-related data**. in fact, many firms struggle not only with data availability, but also with the ability to make meaningful use of it. As Company Beta pointed out**: "***Another challenge that we have is the different methodologies of calculating carbon footprint. So, you know, there's things like economic allocation and physical allocation of carbon. We often get* challenged on what one we're using, and about which is the right one to use for specific categories". These methodological complexities often create confusion, making it difficult for companies to determine accurate environmental impacts. In addition to methodological uncertainty, some companies lack the necessary skills to translate raw data into actionable strategies. As Foodstep observed*: "I think it's the skills with which to understand how to apply that data to their own business… and knowledge around how to actually reduce the environmental impact from there and different strategies that can be used*." This gap in internal capabilities may limit companies' ability to identify priorities or areas for improvement. As a result, platforms that offer not only access to more granular data but also guidance in interpreting it become essential. Mondra highlighted this by stating that, for many companies, *"Our platform provides visibility of data that they've not previously had to understand their impacts."*

DRIVERS		
Brand image/communicate the environmental commitment	Green IS help companies enhance brand credibility by transparently communicating verified environmental efforts.	*"We were able to show our sustainability commitment, and we put a carbon claim on pack for those products in order to communicate to the consumers the benefits of the product"* Company Beta
Declaring reduction target in a standardized way (also for B-corp)	Green IS help companies set, monitor, and report emissions reduction targets using standardized methodologies, especially important for certifications like B Corp or for aligning with net-zero targets.	*"There is currently significant momentum around net-zero targets, such as the 2030 goals. Many companies are engaging in voluntary reporting and making public sustainability commitments. As a result, they often turn to our platforms and services to support and operationalize these efforts."* Mondra
Regulation	While not yet the primary driver,Green IS assist companies in complying with emerging regulations by managing the required environmental data.	*"Compliance from our perspective is less of a driver"* Sustained
Advantage during tenders/in their business	Green IS give companies a competitive edge in tenders by providing reliable environmental data often required in procurement.	*"The motivations stem from competitive pressure … most of our business comes from public tenders. In that contex, they ask for circular economy projects, zero-kilometre products, organic goods"* Company Alfa
Differentiation	Green IS enable companies to stand out by showcasing superior sustainability performance through clear metrics.	*"Working with a platform like ours is a way to stand out against their competitors"* MyEmission
Assurance from data/a third party	Green IS offer external validation of sustainability claims, improving trust and credibility with stakeholders.	*"If we want to talk credibly and externally about a product and its carbon footprint, the platform we are using gives us that level of assurance because it's a third party"* Company Beta
Lack of internal expertise required to analyze and interpret sustainability-related data	Green IS simplify complex sustainability data, helping companies without in-house expertise understand and act on their environmental impact..	*"The platform is just giving them a lot more visibility on numbers and data that they've not previously had to understand their impacts."* Mondra

Table 9: Drivers for the implementation of Green IS in the F&B sector
Source: author's elaboration

The literature and empirical evidence from interviews reveal several points of convergence, as well as some notable differences. One key area of alignment concerns the need for structured and reliable environmental data. Academic sources emphasize that firms require accurate data to understand the environmental impact of their operations, evaluate the effectiveness of sustainability initiatives, and support informed decision-making (*Melville 2010*; *Dangelico and Pujari, 2010*). This was also evident in the interviews, where companies frequently mentioned difficulties in interpreting environmental data and navigating methodological complexities. In this context, digital platforms are perceived as valuable tools for accessing granular data and receiving analytical guidance, thereby helping to overcome internal capability gaps related to the absence of comprehensive standards.

Another point of convergence lies in the role of Green Information Systems in supporting environmental communication directed toward the market. The literature discusses product lifecycle sustainability and the use of digital tools to enhance communication across the supply chain (*Chen et al., 2011*). This was also highlighted in the interviews, where several firms emphasized the strategic use of carbon footprint data and third-party assurance to strengthen brand image and credibility. However, the interviews suggest that many companies adopt these platforms primarily to credibly communicate their environmental commitment to consumers, rather than to enhance transparency along the supply chain.

Significant differences also emerge between the literature and practice. One of the most striking is the role of regulation. While the academic literature often presents regulatory compliance as a primary motivation, the interviews indicate that regulation is not always a driver of Green IS adoption in the food sector. Instead, compliance is perceived more as a future necessity than a current priority. In practice, companies appear more motivated by voluntary commitments and the desire to differentiate themselves from competitors. Interviewees frequently cited brand positioning, consumer trust, and commercial advantage, especially in the context of tenders and B2B relationships, as more immediate and compelling incentives.

Furthermore, although academic studies often distinguish between strategic and operational uses of Green IS (*Butler, 2011*), the interviews suggest that, in practice, these platforms frequently serve both functions simultaneously. Companies use them not only to support long-term sustainability goals but also to manage day-to-day activities, such as preparing environmental claims or meeting buyer requirements. Overall, the interviews portray a more pragmatic and commercially driven picture of Green IS adoption than is typically emphasized in the academic literature.

An interesting finding is that none of the interviewees identified support for green innovation as a primary driver for implementing Green Information Systems (Green IS). This suggests that F&B companies are adopting Green IS mainly for purposes unrelated to innovation or R&D. Instead, the main motivations appear to be enhancing their environmental image or being able to report environmental impact reductions, rather than actively achieving those reductions through innovation-driven efforts.

Talking about drivers is also important to understand the reasons why F&B companies are not implementing certain tools, specifically the **barriers** that prevent them from doing so. While every company interviewed is actively investing in environmental data collection and analysis, not all are using dedicated environmental digital platforms. The existing literature has largely overlooked the reasons why Green IS are sometimes not adopted by companies. To address this gap, this research try to explore these barriers by asking platform providers about the resistance they face in promoting adoption, and by interviewing companies that do not currently use a dedicated platform for managing environmental information. Understanding these reasons could be crucial for Green IS providers to improve their systems and tailor them more effectively to the needs and concerns of potential users The reasons are multiple, but one of the main ones relates to the rigidity of these platforms. For example, Company Delta explained: *"We tried them (platforms) during the research and development phase, but in the end, look, there are situations where these platforms are still a bit, how can I say, structured, rigid. Honestly, they're a little too well-structured for certain situations. We're perhaps not yet a large enough company to reproduce everything exactly as required, and so in the end, it becomes a bit unreliable for us."* Especially for large companies, integrating a platform like that can be challenging due to a **lack of flexibility**. Another issue is that these platforms can sometimes lead to counterintuitive results. As Company Delta noted: *"We had tried platforms where, after a specific development aimed at reducing emissions, the system suggested, for example, sourcing seagull from Chile and then transporting it to Germany and Sweden."*. So, while such suggestions may reduce carbon emissions on paper, they can **lead to inefficient or impractical solutions from other perspectives**. For a company that values sustainable suppliers and controlled sourcing of raw materials, recommendations like these may contradict broader sustainability goals. Company Gamma, on the other hand, has already implemented a simplified version of a Green Information System (Green IS), which allows the company to perform average carbon emission calculations during R&D activities. They also expressed interest in further integrating a more effective digital platforms into their processes. As one interviewee noted: *"There's a plan to give the R&D team the ability to automatically view the average impact of a raw material within our management system as soon as it is associated."* However, the main barriers to implementation are related to limited resources and organizational priorities. As the interviewee explained: *"Right now, our problem is that, due to the merger, the priorities on the IT side are focused on making the group systems homogeneous. So, as a result, the IT department is working on that. We hope that sooner or later there will be time to implement this too, but for the moment, there are no resources to do so"*

4.2.2 Green innovation pathways enabled by Green IS

The second part of this chapter addresses the second research question: "To what extent can Green Green IS enable green innovation?" The objective is to explore how the features of environmental platforms contribute to fostering environmental innovation within the F&B sector, drawing on insights from the interviews. The focus here is not on analyzing individual functionalities in detail, but rather on understanding the broader mechanisms through which Green IS support or enable green innovation. The goal is to identify common patterns and pathways that illustrate how these systems contribute to innovation-oriented sustainability efforts.

A recurring theme across the interviews is the **importance of data to demonstrate the impact of specific innovations**. As one expert noted "*if you don't know how to quantify the effect of a change, there's not a lot you can do about it*". This idea highlights how precise data is essential to inform meaningful sustainability innovations and improvements. As a representative from Company Alfa put it: *"I can certainly confirm that everything must be valued by data, that is, it is nice to tell them but in reality every activity must be demonstrable, made measurable in terms of accounting to have objectives to understand how much the ship has come less close to the result"*. This emphasis on data aligns closely with insights from the Information Systems literature, particularly the Information Processing Theory (IPT). According to IPT, organizations facing complex and uncertain environments, such as those undergoing green innovation, require enhanced information-processing capabilities to support decision-making and coordination (*Qu and Lu, 2022*). Green Information Systems, by enabling the systematic collection, analysis, and communication of environmental data, serve as critical tools to expand a firm's information-processing capacity. In doing so, they not only reduce uncertainty but also strengthen a firm's ability to design, implement, and evaluate sustainability-oriented innovations.

Green innovation in the F&B sector typically follows two main pathways: the development of entirely new products and the improvement of existing ones. In both this pathways the implementation of Green IS is fundamental. The first approach involves creating new products that incorporate environmental sustainability from the start, what is called **eco-design**. In this phase, Green IS playing a crucial role, as they allow companies to define sustainability requirements early in the process and assess what actions are needed to minimize the product's environmental impact. As a representative from Company Beta described: *"If we want to create a seasoning, that goes onto a packet of potato chips, we work with the platform to build out the potato chip on the platform, and we can see all the opportunities to improve that potato chip from an environmental perspective"*. Similarly, Company Delta emphasized the importance of early-stage integration of sustainability considerations: *"We try to anticipate as much as possible, so that both compliance with nutritional criteria and sourcing requirements is ensured from the very beginning"*. Company Gamma also reported implementing eco-design strategies in their product development process: *"We carried out eco-design actions within research and development. By interfacing with our partners and identifying the most impactful raw materials, we modified recipes and, where possible, selected more sustainable suppliers to* *reduce environmental impact."* The strategic inclusion of sustainability during the early design phase is essential, as highlighted by Sustained: *"You bring the environmental considerations into the design stage at the beginning of the process, when it's cheapest to make changes and when it's most effective as well. So before you lock yourself into decisions".*

The concept of eco-design is closely related to what the literature refers to as Environmental New Product Development (ENPD), which involves the integration of environmental considerations into product development processes with the goal of minimizing environmental impact (Pujari et al., 2003). As it emerged from the interview analysis, Green Information Systems (Green IS) can effectively support ENPD by providing visibility into the environmental impact of different product choices directly within the platform. This allows companies to identify and select the less environmentally impactful options from the early stages of product development.

The second approach, often dominant driver in established companies, is that of **improving existing products.** This approach for some companies tends to be more cost-effective and avoids the need to completely redesign the production process. Improvements are frequently achieved through recipe reformulation or changes in sourcing. But this is not true for every company in fact Company Delta said: "*I tend to talk more about improvement, because that's where the real challenge lies...With new products, it's easier, they're created that way from the start; no one knows them yet while with existing product it's really important to maintain the characteristics of the product".* Green IS supporting this process by identifying the most impactful components of a product and enabling companies to model the effects of potential changes. As Company Beta explained *"So, if we have an existing product, we type the recipe into HowGood and see what the product's impact is. Then we can use the platform to see, and maybe we find out that we can optimize this recipe by swapping out some cream for another type of oil and we can also look at sourcing and formulation"***.**

The concept of improving existing products aligns with one of the key benefits of Green IS identified in the literature: enhancing resource efficiency. As highlighted by Hanelt et al. 2017, Green IS can improve the environmental performance of products by supporting companies in optimizing processes and reducing resource consumption. This approach is also closely related to the notion of incremental green innovation, which involves making gradual improvements to existing products. Such improvements may include increasing eco-efficiency, replacing conventional materials with more sustainable alternatives, or designing products for recyclability (De Angelico, 2018). Rather than creating entirely new products, incremental green innovation focuses on refining existing offerings to reduce their environmental footprint.

A related insight that emerged from the interviews is the recognition that innovation often does not stem from revolutionary ideas, but from **small changes**. As Company Alfa noted: "*Sometimes I feel like saying that common sense is the real innovation where it manages to set up those small changes where everyone is willing to take a step back, a step forward depending on the innovation required".* This is particularly relevant in the F&B sector, where companies operate under intense price pressure and may not have the flexibility to implement large-scale transformations. As a result, smaller interventions become more feasible and, importantly, still impactful when applied at a certain scale. As Foodstep highlighted: "I *think the benefit of doing it at scale, like when you've got the integration, is that sometimes when you're looking at this on a product level, the changes don't seem huge, right? Like reducing half a percent of the impact of a product. But when you scale that over the volumes that food products are kind of created and sold at, it's actually quite significant."* This demonstrated how even modest improvements, when multiplied across high production volumes, can yield meaningful environmental benefits.

It was also noted that **Green IS can serve as unexpected triggers for green innovation**, even when green innovation was not the original goal. In several cases, companies initially adopted environmental assessment platforms for purposes such as regulatory compliance reporting or marketing. However, the LCA process often uncovered previously unnoticed environmental hotspots, prompting firms to consider product changes they had not initially planned. As one interviewee form Foodstep explained: *"They perhaps approach us as a marketing piece, but we still find that once we do the assessment and provide all the details, there are occasionally impact hotspots they weren't expecting. At that point, it becomes a really useful conversation: yes, your product may be sustainable in some ways, but it's still not in others and you should be doing better or making changes there*". Similarly, a representative from Sustained emphasized that while environmental optimization may not always be the focus, LCA can uncover hidden opportunities: *"It's unlikely that food companies are going to be able to invest in really focusing and making everything environmentally better. But there will be untapped opportunities they're just not aware of because the data is not integrated within normal workflows."*. As they elaborated further: *"So it's unusual that environmental factors trigger the review of a product. It will be triggered for example by the willingness to reduce salt. But now companies are starting to include the environmental considerations when they do those reviews"* In other instances, **environmental improvements emerged as secondary outcomes from changes that were initially motivated by other priorities**, such as cost savings or other sustainability goals. Using digital platform, companies were able to assess and sometimes validate the environmental benefit of these changes. As another respondent noted: "*It might be an innovation they're making for other reasons, like maybe it's a cost-saving innovation; but they want to understand whether that also* *has an impact on environmental performance".* A notable example of this pattern is found in Company Gamma's development of a recent ice-cream product line. The initiatives began primarily as a socially inclusive innovation aimed at meeting the needs of consumers with dietary restrictions, such as lactose intolerance or celiac disease. As they explained: *"It is a product suitable for them because it has almond as a base and grains are not used... this is a very important social support aspect."* Only in a second moment, through further studies, the company did realize that this formulation also contributed to environmental benefits: *"We verified that it also allows us to reduce CO_2 emissions compared to a classic ice cream based on cow's milk."* In selecting ingredients like almond or soy milk, they also considered sustainability during the sourcing process, though this was not the initial driver: *"Maybe in the choice that was made... we looked for a supply that was also as sustainable as possible."*. Platform providers reinforced this point stating: *"It's not usually that environmental factors trigger the review of a product. But now they're including the environmental considerations when they do those reviews".*

These cases align with what the literature refers to as *serendipitous innovation* (Kamprath & Henike, 2018) and *exaptation* (Codini et al., 2023). Both concepts describe how innovation can emerge unintentionally either through unexpected outcomes (serendipity) or by repurposing existing technologies for new, unintended functions (exaptation). Importantly, these forms of innovation are not the result of pure chance, but rather of preparedness and the capacity to recognize new opportunities within accidental findings. As Kamprath and Henike (2018) argue, to transform an unexpected event into a beneficial innovation, organizations must be equipped with the necessary knowledge base and a mindset open to exploring alternative outcomes. This reflects the idea that "good preparation is essential to work toward the unexpected coincidence and to allow the intellectual leap" that turns an accidental discovery into strategic advantage (Kamprath and Henike, 2018).

In this context, Green IS platforms can be seen not only as tools for data processing or compliance, but also as enablers of serendipity and exaptation, capable of revealing innovation pathways that companies might not have otherwise considered. Their role underscores the importance of creating organizational conditions that are receptive to the unexpected, allowing green innovation to emerge even from unplanned starting points.

Another finding concerns the **iterative nature of product development** in the F&B sector. Green IS were found to be particularly valuable, since innovation in this sector typically requires multiple iterations to reach the right balance between nutrition, cost and environmental impact. Platforms support this by tracking each iteration and providing insights at every stage with minimal effort in terms of cost and time. They also facilitate collaboration between different company departments, such as sustainability and R&D. As Company Foodstep noted: "*This is likely to be an iterative process, in which we engage with the company to define environmental boundaries and collaborate to identify feasible strategies that align with their cost and taste limitations.".* Another added: "*They are going through a lot of rounds of innovation, so they need a solution like ours, which can provide them".*

This observation ties back to the incremental nature of innovation, which is particularly characteristic of the food sector. As noted by Triguero et al. (2018), innovation in this industry tends to occur through gradual improvements rather than radical transformations. In this context, Green Information Systems (Green IS) play a crucial role by enabling companies to track environmental changes over time and support continuous, step-by-step product improvements. By providing detailed data and monitoring tools, Green IS facilitating the iterative process of refining products to enhance their sustainability performance.

4.2.3 Green IS as a tool to manage challenges in green innovation

Finally, the last part of the findings focuses on understanding how green IS can help solve the challenges, trying to answer the following research question: "*Can Green IS address the challenges that characterize green innovation processes?"*

The first part of this section will answer the first sub-question: "*What are the challenges that arise in green innovation processes in the food sector?*" Focusing on the key **limitations and challenges** that food companies face in developing green innovations. The analysis is based on interview data and is compared with findings from the existing literature. The decision to include both F&B companies, as well as platform providers, was intentional. Although platform providers do not produce food directly, they operate exclusively within the food sector and work closely with companies in the industry. As a result, they are well-positioned to identify and understand the practical challenges that businesses face in implementing sustainable innovation.

One of the main challenges is represented by **high costs**. This factor becomes particularly significant in sectors with thin profit margins, where even well-intentioned innovations must be carefully evaluated. As one interviewee from Sustained noted: *"Like if you prefer having a higher environmental impact rather than an increased cost, it's a big decision for companies because the sector is really very cost competitive".* In some cases, innovating a product in an environmentally sustainable way requires the active involvement of suppliers in the adoption of sustainable practices, which often leads to increased financial pressure. As Company Delta observed: "*The critical point is that these are costs. Behind all of this, there are costs because, as you can imagine, applying the*

"Carta del Mulino" to farmers means supporting their income; it means guaranteeing their income." Similarly, Company Gamma acknowledged that transitioning toward more sustainable products results in a *"higher cost to its supplier"*, which *"involves a higher cost for the company but also for the consumer"*.

This issue is closely linked to the broader challenge of **lack of consumer awareness**. As Company Alfa pointed out: *"It costs double, so you must be earning double."* However, they added, *"that's not how it works."* Company Delta also emphasized the lack of consumer willingness to pay more for sustainable products, stating: *"In the end, the company has to absorb these costs without transferring them to the consumer, because ultimately the consumer will end up choosing what costs less. And this is a difficulty [which] blocks many new ideas and limits the innovations that could be made."* In a highly competitive market, demand for more sustainable or organic products is increasing, yet the prices that companies receive often remain unchanged. This imbalance leads to greater business risk and shrinking profit margins, as the higher costs associated with green innovation do not necessarily translate into increased revenue, largely because consumers are not willing to pay a premium.

Another major challenge is the **uncertainty,** particularly regarding reporting standards and regulatory obligations. Many companies are in fact, hesitant to invest in green innovation without clear visibility on whether such efforts will be rewarded or required in the future. So, uncertainty is linked to rapidly evolving regulations, which often lack clarity as Sustained said: *"Particularly with things like uncertainty on regulation, it's the kind of thing that sometimes companies will push down the road until it's a must have."*. This creates risk for companies investing in innovation without knowing how future compliance will be measured or enforced. But uncertainty also extend to customer's preferences. Company Alfa described this by saying: *"Innovation is always one step ahead. Customers don't always ask for certain things, not because they don't need them, but because they haven't yet realized their value. What we choose to do is stay ahead of the curve, anticipating their needs and casting the bait before they even know they're ready."*

A further limitation is the **lack of expertise**. As described by company Foodstep: "*There's also a gap in knowledge around strategies to reduce environmental impacts*". While companies often set environmental targets, implementing green product innovation requires different skill sets and technical know-how. Company Beta commented: *"Many of the food companies we work with have created these net zero pathways or commitments to reach net zero by 2050. But a lot of the time, they don't know how they're going to get there."*. Another interesting trend highlighted by Company Delta is that, for some products, reducing environmental impact and improving nutritional value now requires entirely new approaches. Traditional strategies like reformulation or sourcing from different suppliers have already been applied. As Company Delta explained: *"Many products have been already improved with existing technologies, now we have to find solutions and technologies that no one knows. So it is no longer like removing or replacing with an ingredient rather than another, we are searching for new technologies and studying many novel foods"*. Lack of expertise not only refers to the technical knowledge required to reduce environmental impact, but also to the capabilities needed to access and interpret environmental data. As Mondra explains: "*In some cases, the data simply doesn't exist or is very difficult to obtain. As a result, companies struggle to identify areas for reduction because without data, you don't know where to take action."*

Companies often face **trade-offs between sustainability and other product dimensions**, such as nutritional quality and taste. Company Delta highlighted this as a key challenge: the need to improve a product's environmental performance without altering the original characteristics that consumers associate with its taste. As they explained: *"The challenging thing is bringing existing products in line with ESG criteria, with green criteria, without changing the characteristics of the product ... it's really important to maintain their characteristics, doing everything possible but without making sacrifices of taste."*. For example, discussion around alternative protein reflect tensions between environmental and nutrition goals. One company noted: "*The concern around the health implications of ultra-processed foods has a significant impact on the alternative protein sector*". Company Mondra added: "*A vegan diet looks really good from a planetary carbon perspective, but not necessarily from a nutritional perspective*". Thus, an overemphasis on environmental performance may sometimes lead to negative outcomes on the nutritional front. However, this is not always the case like Company Beta said: *"If you reduce the sugar content in a beverage and replace it with some flavourings or sweeteners, you are lowering its carbon footprint, reducing calories and sugar, and making it a more nutritious product overall"*.

Finally, several companies reported a **lack of alignment within the organization,** which often limits progress on sustainability initiatives. This includes misalignment between sustainability teams and top management, as described by My Emission: *"I think the biggest challenge is when you work with bigger organisations, is that internally they're maybe not aligned. Sustainability teams are constantly fighting that battle inside their organisation to get them to reduce emissions."* This challenge was echoed by Company Gamma, which emphasized the importance of leadership alignment: *"There are some actions that if there was not the sustainability group that gives the direction, they would not be taken"*. Misalignment also occurs between R&D and sustainability teams. Company Alfa identified resistance to change as a major barrier: *"The biggest barrier is resistance to change. It's often easier to accept the pain and rising costs than to take a risk on something new, especially when it addresses needs that aren't fully recognized yet. And the first thing they ask me is always: 'Is it working?'.*

Table 10 will summarize the various categories of challenges that companies are facing in developing green innovations, according to our interviews.

CHALLENGES		
HiGH COST	Companies in the F&B sector operate with low margins and cannot pass higher costs to consumers, limiting the feasibility of green innovations.	*"Margins are tight and the macro environment is more difficult for food companies at the moment. And, you know, things like tariffs happening, it's going to get more difficult. So cost is much of a priority"*
LACK CONSUMER AWARNESS	Consumers are often not willing to pay more for sustainable products, weakening the business case for innovation.	*"The consumer will end up choosing what costs less. And this is difficult—it blocks many new ideas and limits the innovations that could be made."*
REGULATORY and MARKET UNCERTAINTY	Companies postpone innovation until regulations become mandatory; uncertainty also exists around evolving consumer preferences.	*"The first barrier is that we are working on something that's not yet clearly defined"*
LACK OF EXPERTISE	Strongly emphasized: companies struggle with data interpretation, method selection, and impact assessment.	*"There is a gap in knowledge and expertise needed to actually reduce environmental impact"*
TRADE-OFFs WITH OTHER GOALS	Seen as a major F&B-specific challenge—e.g., balancing low carbon footprint with nutritional quality and taste preservation.	*"The challenging thing is bringing existing products in line with ESG criteria, with green criteria, without changing the characteristics of the product "*
INTERNAL MISALIGNMENT	Misalignment between sustainability teams and R&D/top management is a central barrier; often blocks implementation of green strategies.	*"I think the biggest challenge is when you work with bigger organisations is that internally they're maybe not aligned"*

Table 10: Main challenges for the development and implementation of green innovation
Source: Author's elaboration based on the interviews analysis

Table 11 below will highlight what are the connections between the two set. Although many of these challenges align with those identified in the literature, it is important to note that some are specific to the F&B sector.

In line with prior research (Dangelico and Pujari, 2010; De Marchi, 2012), high costs remain a key barrier to green innovation, particularly in sectors with tight margins such as F&B . Another area of convergence is the uncertainty around regulations and market expectations. Both the literature and the interviews highlight the hesitation of companies to invest in green innovation when future requirements or consumer preferences remain unclear. However, the interviews also reveal challenges that are either underdeveloped or overlooked in the literature. For instance, while academic studies acknowledge technological and organizational complexity (De Marchi, 2012; Pujari et al. 2003), the interviews emphasize not only a general lack of internal expertise but also specific difficulties in analysing and interpreting sustainability-related data. Many companies report struggling to assess their environmental impact, choose appropriate foot printing methodologies, and translate results into actionable strategies: issues that are only marginally addressed in existing research.

Another point of divergence concerns the trade-offs between environmental goals and other product priorities, such as nutrition, taste, or safety. This emerged from the interviews as a significant challenge in the food sector, but it has not been identified as such in the literature. The likely reason is that most academic studies take a cross-sectoral approach, while this thesis focuses specifically on F&B, where such trade-offs are particularly pronounced.

Finally, internal misalignment, whether between departments or between sustainability teams and top management, emerged from the interviews as a concrete barrier to implementation. While the literature refers to communication issues (Dangelico and Pujari, 2010) and cultural resistance (Pujari et al., 2003), the interview data suggest that these factors should be understood not as barriers in themselves but as root causes of misalignment. In this sense, the interviews provide a more granular understanding of how internal dynamics can hinder the effective deployment of green innovations.

CHALLENGES	LITERATURE EVIDENCE	INTERVIEW FINDINGS
HiGH COST	Green technologies require high upfront investment; difficult to compete without subsidies *(Dangelico & Pujari, 2010).*	Companies in the F&B sector operate with low margins and cannot pass higher costs to consumers, limiting the feasibility of green innovations.
LACK CONSUMER AWARNESS	Consumers are often not willing to pay more for sustainable products, weakening the business case for innovation.	Consumers are often not willing to pay more for sustainable products, weakening the business case for innovation.
REGULATORY and MARKET UNCERTAINTY	Lack of clear standards or stable expectations discourages investment (*Dangelico & Pujari, 2010*).	Companies postpone innovation until regulations become mandatory; uncertainty also exists around evolving consumer preferences.
LACK OF EXPERTISE	Green innovation requires advanced skills and expertise often lacking in traditional companies (*De Marchi, 2012*).	Strongly emphasized: companies struggle with data interpretation, method selection, and impact assessment.
TRADE-OFFs WITH OTHER GOALS	Not addressed explicitly in general literature.	Seen as a major F&B-specific challenge—e.g., balancing low carbon footprint with nutritional quality and taste preservation.
INTERNAL MISALIGNMENT	Communication and cultural resistance mentioned as obstacles (*Pujari et al., 2003*).	Misalignment between sustainability teams and R&D/top management is a central barrier; often blocks implementation of green strategies.

Table 11: Comparison of the categories of challenges faced in the development and implementation of green innovations
Source: Author's elaboration

After having analysed the challenges that has emerged from the analysis and compared them with the literature review answering to the first sub-research question. We moved forward to answer the second sub-question: "*What are the resolution mechanisms enabled by Green IS to address green innovation challenges?*"

This section examines how the functionalities of Green Information Systems (Green IS) can help overcome the challenges encountered during green innovation processes. To achieve this, the analysis builds on the key issues identified in the previous sections by linking specific Green IS functionalities, defined in the previous chapter, to each challenge. The aim is to uncover the underlying mechanisms that explain how each functionality can contribute to resolving a particular challenge.

One significant functionality related to the implementation of Green IS is their ability to **integrate suppliers in the innovation activities of the companies.** This collaboration can directly support the development of new product. As Mondra explains: *"when it comes to product development, retailers rely heavily on their supplier. For example, a complex product, like a lasagna ready meal, they outsource to a supplier to build the product. They provide a brief with requirements to create the product."* This reliance is particularly important when it comes to improving environmental performance. As Company Beta noted: *"Companies don't know how they're going to reach commitments to net zero... and they're relying on their suppliers to have innovations in place that create lower carbon emissions."* Sharing data with suppliers through platforms enables faster identification of sustainability opportunities and helps compensate for the lack of in-house expertise. Moreover, platforms allow suppliers to input their own data, increasing transparency and precision. Given that raw materials are a major source of emissions, having up-to-date, detailed data from both new and existing suppliers is essential. To facilitate this, Mondra has developed a system that allows brand owners to share product information securely, without requiring suppliers to disclose sensitive proprietary data. Another example comes from Company Delta, which developed a digital platform to engage farmers in a precision farming initiative. The platform not only supports farmers in adopting precision agriculture techniques to improve their yields, but also enables Company Delta to quantify the environmental benefits. By using the platform's database and conducting LCA calculations, Company Delta was able to demonstrate the reduction in carbon emissions associated with precision farming practices. Furthermore, the large volume of data collected has fostered collaborations with universities to study additional benefits, such as the positive impact of these practices on soil organic matter improvement. Moreover, involving the supplier involving the supplier from the early stage through Green IS can reduce cost but also the supplier can find new and cheap ways of reducing the environmental impact of your product.

Another valuable functionality is the **integration of environmental platforms** with other tools used during the various R&D phases. This allows companies to "*incorporate nutritional information and environmental impact, so to analyze them together and highlight where these trade-offs are*" (Mondra). As Mondra highlights, this makes it possible to manage the trade-offs that may emerge between nutritional value and environmental considerations. For example, Company Beta was able to integrate the green IS they use with other types of data employed during product development. As they shared: *"we were looking at the nutritional value and the environmental impact and the taste and the cost all at the same time when we were designing that product from scratch.*" The integration of environmental platforms with other information systems also facilitates the communication between ESG team and R&D departments. By accessing shared data, R&D teams can better understand how their decisions impact environmental performance. Having access to the same data streamlines collaboration and facilitates co-development, as Mondra underlines: "*Simply having the same data and being able to work with them on product development makes collaboration a lot easier."* One example comes from a client who has integrated their recipe management system with the platform*: "And one of our clients, for example, has an integration between their recipe management system that they use, Recipe Professor. So during new product development process they have carbon data there as well."*. Finally, this integration also improves data accuracy and reduces the time and effort required by companies to provide information about their products. By linking the platform directly to the recipe management system, the platform automatically receives all the necessary data for impact calculations, making the process faster and more efficient. As noted: As Sustained noted: *"We integrate with tools food and beverage manufacturers are already using. For example, at Complete Food Group, their food designers use Recipe Professor. It's integrated with our platform, so we pull product data from there, calculate environmental impact, and feed the results back."*

Another important way in which Green IS can promote green innovation is through their ability to **calculate and interpret data.** Many organizations lack the expertise to effectively manage or acquire environmental data. Green IS address this gap by processing, contextualizing, and translating large volumes of data into actionable insights, enabling companies to make more informed decisions. This capability is particularly valuable in reducing uncertainty**,** as it provides clarity and confidence about the environmental improvements achieved through product changes or innovations. Crucially, the ability to translate data into meaningful insights also helps foster internal alignment around sustainability goals. Credible data makes it easier to gain support not only from top management but also from other departments. As Mondra explained: *"It is easier to get approval from the top management... because they need the data to prove what they're doing. So I would say you need the data to prove the benefit to then get buy-in from people."* Similarly, Foodstep emphasized the value of expert guidance and reliable data in gaining internal support: *"Providing that kind of certainty, that what's being recommended is both best practice and likely to have a real impact, is valuable. Having an expert voice involved definitely helps in getting your idea approved by other functions."* Sustained also highlighted this benefit, describing how one large multinational company uses the data, graphs, and insights provided by their platform to support both existing and new product development. *"They incorporate these insights into project group presentations to inform and guide business leads. For example, in a typical six-month project, such as relaunching an existing product* *like a sausage roll, the R&D team reviews the environmental insights on a monthly basis and makes recommendations to the business and development teams on potential actions to take"*. Moreover, the ability to generate clear and understandable data insights can help companies raise consumer awareness by showcasing their environmental efforts and helping consumers understand the importance of choosing products with a lower environmental impact.

Another essential functionality offered by Green IS is the ability to **identify emission hotspot**, areas within the product lifecycle or organizational operations that contribute most to environmental impact. This capability enables companies to focus their sustainability efforts where they are most needed and effective. As My Emissions explained: "*The first thing you can do is see where the hotspots are, where you might have like an idea about it before that, you know, basically what is driving most emissions, and then you know what to focus on.* By revealing the most emission-intensive components, platforms enable companies to develop targeted strategies for carbon reduction. In some cases, reducing environmental impact can be as simple and cost-effective as switching an ingredient or a supplier. This process provides clarity and direction, helping organizations move beyond general sustainability intentions toward focused, data-driven action. Company Gamma, a company making ice creams and related products, illustrated how this mechanism supports continuous improvement, stating that after conducting their Life Cycle Assessment (LCA), they used it *"as a point to understand areas to improve,"* particularly across Scope 1, 2, and 3 emissions. These insights enable companies to translate raw data into concrete plans for emissions reduction, making hotspot identification a crucial first step in any data-driven sustainability initiative. Also Company Delta, even without relying on a specific digital platform, recognized LCA as a crucial starting point for identifying areas of improvement. As they explained: "*Then on all our products we have the calculation of the LCA, we do it for everyone, in such a way that from the LCA, from the calculation of the LCA, we say, we take a cue for those that are all the elements of recovery, then of reduction of energy consumption, etc., etc."*. For these reasons, the hotspot identification functionality can also help compensate for a lack of internal expertise in managing green initiatives. Green IS tools make it easier to understand where to begin and which actions are likely to be most impactful. Additionally, by clearly visualizing where the highest emissions originate, these platforms address the common challenge of data interpretation, enabling more companies to turn raw information into meaningful sustainability strategies.

The last functionality analyzed is **scenario analysis**, which enables companies to compare the environmental performance of existing and potential product formulations. This tool supports not only product-level reformulation decisions but also broader environmental strategy by visually illustrating how specific modifications impact overall emissions, thereby reducing uncertainty. As

My Emission explained: "*it basically compares the high-level figures like the total emissions they're rating, but also puts the like, different emission sources side by side so you can see what like, makes the difference.*". This comparative view allows companies to simulate the outcomes of proposed changes before implementation. F

For example, Foodstep described how this functionality helps assess reformulation options "they can create hypothetical versions of the produc and say *if I change my product like this, its environmental impact would go down (or up), so maybe I should, or shouldn't, make that change*". The ability to simulate changes in advance reduces the risk and cost of trial-and-error decisions made later in the development process. Company Beta also highlighted the practical value of this functionality, particularly in identifying the most impactful ingredients: *"We can identify that, this ingredient has the highest impact. Let's change the sourcing or let's change the quantity of that ingredient to improve the impact for our customer."* This further illustrates how Green IS can help address the lack of expertise. Many companies struggle to fully understand the environmental consequences of their product decisions by using structured platforms, they not only gain clarity on the effects of proposed changes but also learn how to innovate in a more sustainable way. Beyond ingredients and formulations, platforms often provide a detailed overview of the full product life cycle. As Sustained explained: *"You have an interface that shows each life cycle stage of the product: raw materials, production steps, distribution, end of life. And between those, the transport modes. Someone can go in and play around with the formula: how much of this we put in, can we swap this, should we rethink transport, or change the country of origin? That's really where the magic is in terms of reducing environmental impact and innovating more sustainably."* In this way, scenario analysis empowers firms to explore, test, and prioritize product changes, leading to more informed, evidence-based decisions and ultimately enabling more targeted and impactful green innovation.

Table 12 summarize the concepts developed above explaining in a visual way what is the connection between the platform functionalities and the challenges that companies are facing in green innovation processes explaining what the underlying solving mechanism is. The connections identified are based on insights drawn from the interviews. In some cases, these links were made explicit by the companies themselves, while in others they were inferred from the dynamics and examples described. For instance, the connection between *environmental data calculations and interpretation* and *lack of internal misalignment* is strongly supported by interviewees who emphasized how reliable, shared data can facilitate alignment between sustainability teams, R&D, and top management. Similarly, the integration of environmental platforms with other management systems was frequently described as a key mechanism to ensure smoother collaboration and co-development processes across departments.

By contrast, some connections, such as the one between "hotspot identification" and "lack of expertise", were not directly stated but can be reasonably interpreted from the context. In this case, while no company explicitly framed hotspot tools as a solution to capability gaps, many described how identifying emission-intensive areas gave them a clear starting point and simplified decision-making, which suggests that this functionality effectively supports organizations that lack in-house expertise in sustainability.

In summary, even if these connections are not always explicitly affirmed by the interviewees, they represent a valuable interpretation of the mechanisms described. This mapping offers a promising basis for future research, which could further explore and validate these insights using quantitative methods such as structured surveys or broader-scale studies. Such work could contribute to building a more systematic understanding of how specific digital functionalities help companies overcome the challenges of green innovation.

CHALLENGES	Supplier integration solution	Integration with other management systems	Environmental data calculations and interpretation	Hotspots identification	Scenario analysis tools
COST	Involving the supplier from the early stage can reduce cost but also the supplier can find new and cheap ways of reducing the environmental impact of your product			Through the platform it will be possible to find easy and cheap way to reduce the impact by just switch an ingridient or a supplier	By simulating the environmental outcomes of different options, companies can avoid costly trial-and-error processes
CONSUMER AWARNESS			Clear data insights help companies raise awareness by guiding consumers toward low-impact choices.		
UNCERTAINTY			Having a number certified from a third party can help overcame the uncertainties		It visualizes the outcomes of different choices, making decisions more confident and data-driven
LACK OF EXPERTISE	Platforms can allow the supplier to share its data automatically without sharing information that wants to keep protected. Also benefit from the supplier expertize on a certain area	Integrating the environmental platform with the recepie management system of the company can help having more precise data and authomatically updated		This functionality make it easier to understand where to begin and which actions are likely to be most impactful	The platform clearly shows the impact of each option, helping teams understand what changes reduce emissions even without deep technical knowledge.
TRADE-OFFs WITH OTHER GOALS		Integrate different consideration in the innovation process			
LACK OF INTERNAL MISALIGNMENT		Having environmental data accessible to every function of the company can help people understanding the importance of reducing envorinomental impact and also understand what is the impact of their changes	Having precise calculations and easy to understand graphs able to explain to the other function the future environmental reduction of the innovation can overcome resistance a solve doubts from the top management		

Table 12: Overview of Challenges and Related Green IS Solving Mechanisms
Source: author's elaboration

5. Conclusions

The objective of this thesis was to explore the role of Green Information Systems (Green IS) in supporting sustainability-oriented innovation within the food and beverage (F&B) sector, a domain characterized by high environmental impact and growing pressure to transition toward more sustainable practices. Specifically, after investigating the broader context of environmental sustainability in the F&B industry and analyzing the existing literature on green innovation and digital solutions, the following research questions were defined:

1. *What are the drivers that motivate food and beverage companies to implement Green IS?*

2. *To what extent can green IS enable green innovations?*

3. *Can Green IS address the challenges that characterize green innovation processes?*
   3.1 What are the challenges that arise in green innovation processes in the F&B sector?
   3.2 What are the resolution mechanisms enabled by Green IS to address green innovation challenges?

To answer these questions, the thesis adopted a qualitative research approach based on a two-step empirical investigation. First, an in-depth analysis of selected Green IS platforms operating within the F&B sector was conducted with the aim of identifying their core characteristics and functionalities. This mapping enabled a better understanding of how these systems operate in practice and what types of services they offer to support sustainability initiatives and innovation processes. Second, semi-structured interviews were conducted with key stakeholders, including platform providers and F&B companies. This approach allowed for a dual perspective on the role of Green IS, capturing both the supply and the demand side The findings from this stage provided valuable insights into the motivations that drive companies to adopt Green IS. These include the need to (i) improve brand reputation, (ii) respond to increasing demands for transparency, (iii) differentiate in a competitive market, (iv) gain a strategic advantage in tenders, (v) obtain credible data for external reporting (e.g., B Corp, CSRD, SBTi), and (vi) address the lack of internal expertise in managing and analyzing environmental data. Notably, contrary to what is often suggested in the literature, regulatory compliance did not emerge as a primary driver at this stage, though it is expected to gain importance in the near future.

The interviews also highlighted that companies rarely adopt Green IS with the explicit goal of supporting innovation. However, according to our findings, innovation-related benefits often do emerge indirectly. In line with the Information Processing Theory (IPT), Green IS enhance companies' ability to manage complexity and uncertainty by providing access to structured, granular, and standardized environmental data. These data are essential to support both the development of new sustainable products (eco-design) and the improvement of existing ones (incremental innovation). Moreover, the findings of this study highlighted that Green IS can act as enablers of serendipitous innovation by revealing unexpected environmental hotspots and triggering product reformulation or supply chain adjustments that may not have otherwise been considered.

To further address the third research question - "*Can Green IS address the challenges that characterize green innovation processes?*" - the key challenges that companies face in implementing green innovation were identified. They include high costs, lack of internal expertise, misalignment across departments, conflicting product goals (e.g., taste vs. sustainability), and uncertainty regarding regulations and consumer expectations. These challenges were then matched with the functionalities offered by Green IS platforms, such as hotspot identification, scenario modelling, supplier engagement, and integration with R&D tools. The analysis highlighted not only the practical mechanisms through which these systems can alleviate innovation-related tensions, but also their potential strategic role in guiding decision-making and improving cross-functional collaboration.

Nevertheless, this study is not without limitations. First, the qualitative and exploratory nature of the research implies that findings cannot be generalized to the entire F&B industry. The sample of interviewed companies was relatively small and mostly composed of firms already engaged in sustainability efforts. A larger and more diverse sample could have allowed for a more granular comparison between the perspectives of platform providers and F&B companies, better highlighting potential mismatches between user needs and available solutions. Furthermore, while the research focused on identifying correlations between platform functionalities and innovation challenges, it did not measure the actual performance or environmental impact of implemented solutions. This is an area that would benefit from quantitative follow-up studies.

From a practical standpoint, the study suggests that F&B companies could benefit from integrating Green IS tools directly into their R&D processes, using these platforms not only to report impact but also to guide product development and manage trade-offs between sustainability, cost, nutrition, and taste. Green IS can also serve as a bridge between departments, helping improve internal alignment and communication around environmental goals. For platform providers, the research highlights the importance of improving integration with existing enterprise systems and offering more tailored support to address the specific data interpretation challenges faced by companies in this sector.

Another limitation concerns the rigidity of current Green IS platforms, as mentioned by some companies during interviews. While these systems are designed to promote standardization and comparability, their structure may at times be too inflexible or insufficiently customizable to accommodate the specific needs of certain firms. This insight suggests that further research could also help platform developers refine their tools by incorporating more adaptive, user-centered features.

Ultimately, the findings of this thesis contribute to the growing body of research on green innovation and digital sustainability by offering a sector-specific perspective that connects Green IS functionalities with practical innovation needs. For F&B companies, this study may serve as a useful starting point to better understand how digital systems can support their sustainability journey, not just in terms of compliance or communication but as enablers of innovation and strategic transformation. At the same time, the research offers actionable insights for Green IS providers seeking to improve platform design and align more closely with the evolving needs of the food industry.

As environmental data becomes increasingly central to innovation processes, future research should further investigate how information systems can be integrated into decision-making frameworks to support systemic change. Exploring the dynamics between data quality, user adoption, and innovation outcomes could provide a deeper understanding of how to unlock the full potential of Green IS in the transition toward a more sustainable food system.

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