NOVA SCHOOL OF BUSINESS & ECONOMICS

Blockchain-enabled Carbon Traceability:

Analyzing Its Impact on Firm Performance in the European Retail Sector – Employee Attraction and Retention

Greta Achten (58059)

Work project carried out under the supervision of:

João Castro

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Abstract

This thesis analyzes the impact of blockchain-enabled carbon traceability on firm performance in the European retail sector using a multidimensional approach. Findings reveal that blockchain-enabled carbon traceability positively impacts firm performance through improvements in supply chain performance, employee attraction and retention, and stock price performance. However, these effects rely on essential enablers. No effect on consumer purchasing behavior is observed. The study provides recommendations across five dimensions to maximize blockchain-enabled carbon traceability's potential. It contributes to research by investigating blockchain's role in carbon emissions traceability and its broader effects on firm performance, rather than focusing on isolated metrics.

Keywords: Carbon Traceability, Blockchain, Retail, Firm Performance, Transparency

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1. Introduction

In 2019, European Commission President Ursula von der Leyen announced Europe's ambition to become the world's first carbon-neutral continent by 2050. Despite the EU's efforts under the European Green Deal (EGD), progress toward this goal has been insufficient. Climate change has caused €145 billion in damages in the EU over the last decade and is expected to increase significantly in the coming years (European Commission 2022a). To combat this, greenhouse gas (GHG) emissions must be reduced considerably.

However, one industry expert interviewed for this thesis emphasizes, *"You can't improve what you can't measure"* (I7). This highlights a critical challenge: most businesses lack a basic understanding of their emission levels, particularly Scope 3 emissions (Alves, Vieira, and Partyka 2023; Yavari et al. 2023). These include all indirect emissions beyond a company's direct control - such as those from suppliers, transport, and product use or disposal – and are challenging to measure due to difficulties in obtaining data, reliance on supply chain (SC) partners, variability in data sources, and complex interdependencies (Hertwich and Wood 2018). Monitoring, reporting, and verifying (MRV) Scope 1 and 2 emissions is more straightforward. Scope 1 covers direct emissions from company-owned sources, and Scope 2 includes indirect emissions from purchased energy, such as electricity or heating (Callahan et al. 2011; Hettler and Graf-Vlachy 2024). Identifying carbon emissions across all three scopes is defined as carbon traceability (ISO 1994). It is a foundational element for addressing regulatory compliance and voluntary sustainability initiatives, enabling full environmental transparency across an organization's value chain (Lee 2012; Kaur et al. 2024).

Under the regulations set by the EGD, specifically the Corporate Sustainability Reporting Directive (CSRD), starting in 2025, companies must disclose their emissions across all three scopes (European Commission 2023a). This is particularly challenging for the retail sector, which faces

significant challenges in tracing and reporting carbon emissions due to the complexity of retail SCs, diverse product portfolios, and especially the dominance of Scope 3 emissions, which account for 98% of total emissions (McKinsey 2024a). As intermediaries between producers and consumers, Europe's retailers play a crucial economic role, generating €3.2 trillion in trade and contributing 20% of EU GDP in 2022 (Statista Research Department 2024a; Nolan, Zhang, and Liu 2007; Eurostat 2024). This economic significance underscores the urgency of addressing carbon traceability challenges in the retail sector, which demands innovative methods that enable comprehensive emissions reporting while ensuring financial viability and aligning sustainability strategies with accurate data on carbon footprints (Dhanda, Sarkis, and Dhavale 2022). Blockchain (BC) technology is currently gaining recognition as a tool for managing and tracing carbon footprints, especially Scope 3 emissions, and resolving issues of trust and cooperation among stakeholders (Kadry 2022). Its core features – immutability, decentralized verification, and real-time traceability – can potentially provide a framework for identifying and verifying emissions data across complex SCs (Munir et al. 2022; Huang, Weber, and Matthews 2009). F.e., the U.S. retailer Walmart piloted BC for carbon traceability with mangoes in the U.S. and pork in China, showing its effectiveness. The system increased transparency by tracing emissions data at each stage of the SC, holding suppliers accountable through carbon scorecards, and sharing environmental impact information with consumers (Tan et al. 2018; Sharma and Kumar 2021).

Despite growing interest in BC technology, current literature primarily centers on social sustainability or product origin information through BC, leaving gaps regarding carbon traceability (Liu, Wang, et al. 2023; Fraser and van der Ven 2022; Biswas et al. 2023). However, even within this scope, existing literature predominantly focuses on isolated SC performance, neglecting its broader implications for overall firm performance (Saberi et al. 2019; Cui, Gaur, and Liu 2023).

Additionally, the specific impact of Blockchain-enabled carbon traceability (BCCT) on firm performance within the European retail sector and other firm performance dimensions and synergies remain unexplored (Kamble et al. 2021; Wamba and Queiroz 2022; Carmeli, Gilat, and Waldman 2007). Therefore, this study addresses the following umbrella research question (RQ):

Umbrella RQ: *How does BCCT impact firm performance in the European retail sector?*

To address the umbrella RQ, we adopt a multidimensional approach, integrating theoretical insights from existing literature with empirical findings to explore the dimensions of BCCT - specifically from the SC, purchasing behavior, talent attraction and retention, and stock price perspective - and their impact on firm performance. This study contributes to existing research by offering a more holistic understanding of the factors influencing performance from an intrinsic firm perspective. Furthermore, it provides actionable implications for effective implementation within the European retail sector.

This thesis is structured as follows: Section 2 provides a theoretical foundation for the thesis. After presenting the methodology in Section 3, Section 4 summarizes the key findings of the other individual parts from the collective thesis. Section 5 then looks at internal dynamics, analyzing how BCCT adoption affects employee behavior, particularly regarding attraction and retention. Sections 8 and 9 integrate these insights and examine their cross-dimensional impact on firm performance, leading to practical implications. The study concludes by synthesizing findings, addressing limitations, and suggesting directions for future research, providing a comprehensive and structured examination of this emerging field.

2. Background

This section sets the groundwork for analyzing BCCT's impact on firm performance. Section 2.1 outlines the regulatory framework, Section 2.2 examines the current state of the art in carbon

traceability, Section 2.3 explores carbon traceability in the retail sector, and Section 2.4 explains BC technology.

2.1. Regulatory Framework

As part of the EGD, the CSRD mandates Environmental, Social, and Governance (ESG) reporting for EU and non-EU firms with considerable operations in the EU. Social disclosures emphasize human rights, diversity, and labor practices, while governance requirements target corporate ethics, anti-corruption measures, and the integration of sustainability into strategic decision-making. This study focuses on the Environmental Pillar of the ESG, which addresses climate-related risks, GHG emissions, and resource consumption (LSEG 2024). According to the CSRD, organizations must trace and report their Scope 1, 2, and 3 emissions quarterly, completing over 200 mandatory fields on an EU portal. For the fiscal year 2024, large public-interest entities with over 500 employees must comply with stricter regulations. For the fiscal year 2025**,** the mandate expands to include large companies reaching at least two criteria: more than 250 employees, a net turnover exceeding €40 million, or total assets over €20 million. Listed small and medium-sized enterprises must comply with the reporting requirements starting in fiscal year 2026, but they can delay compliance until 2028 (European Commission 2023a). Non-EU firms must disclose emissions to access the EU market, promoting comprehensive carbon emission data (Perdana and Vielle 2022).

In practice, the stricter regulations pose significant challenges for many companies across Europe, particularly in independently determining the carbon emissions generated by their overseas suppliers. The EU Commission advises businesses to request carbon emission data directly from them. However, this process can be costly and complicated, especially in multi-tiered SCs where data reliability may be difficult to ensure (BDI and DIHK 2024). Therefore, many companies

remain unprepared to meet regulatory requirements, which can result in financial penalties and exclusion from the market (De Villiers, La Torre, and Molinari 2022; Lütkehaus et al. 2022).

2.2. Current State of the Art in Carbon Traceability

Implementing a robust carbon traceability system may offer significant advantages for companies navigating the European regulatory landscape. Firms must ensure near real-time, verifiable, and detailed tracing of individual product emissions while safeguarding business confidentiality and proprietary information (Harbich et al. 2021; Heiss et al. 2024). MRV systems are a common tool for this. In the monitoring phase, companies collect activity data, quantifying business operations that generate GHG emissions. These activities are then translated into emission estimates using emission factors, which are standardized, projected coefficients, often derived from databases like those provided by the Intergovernmental Panel on Climate Change (Heiss et al. 2024). Life Cycle Assessment (LCA) is often used in this context. LCA is a systematic method for evaluating the environmental impacts of products, processes, or services across their entire lifecycle, from raw material extraction to disposal (ISO 1997). In the reporting phase, the calculated emissions are compiled into a report, which must adhere to key accounting principles: relevance, accuracy, completeness, consistency, and transparency. These principles aim to enhance the reliability of the data but cannot entirely mitigate the limitations of approximation (WRI and WBCSD 2011). Finally, verification involves a third-party review to confirm the report's compliance with guidelines and regulatory standards (Heiss et al. 2024).

Conventional MRV systems are limited by long, annual reporting cycles and centralized structures that reduce transparency and trustworthiness (European Commission 2023a; European Commission 2023b). Furthermore, the systems often lack sufficient digitization and automation, resulting in higher costs, increased errors, and inefficiencies (World Bank 2022).

2.3. Carbon Traceability in the Retail Industry

As mentioned before, this thesis focuses on the retail industry, which includes all activities involved in providing goods or services directly to end consumers for personal and non-business objectives. These activities can occur in physical stores, online platforms, or other formats. Given the large share of indirect emissions in retail paired with its vast reach and impact, the sector holds considerable potential to drive large-scale environmental improvements by employing cutting-edge carbon tracing methods (McKinsey 2024a; Ferreira et al. 2019).

However, retail SCs differ from other industries in several ways, making carbon emission traceability more challenging. Retail SCs are inherently more complex than other industries due to the larger and more diverse network of suppliers that retailers must manage (Ge et al. 2019). This diversity arises from a wide product range sourced from various regions and production stages, in contrast to manufacturers who often operate within more streamlined and vertically integrated SCs. Additionally, retail SCs tend to be highly dynamic, as retailers frequently adjust their supplier base to respond to shifts in consumer demand, cost pressures, or seasonal variations. This dynamic nature further complicates establishing and maintaining consistent carbon traceability systems across the SC (Serdarasan 2013). Fragmented data-sharing systems exacerbate these challenges, as multi-level SC stakeholders use inconsistent standards, resulting in incomplete data. Process standardization, regional differences, language barriers, and infrastructure accessibility further complicate carbon traceability in the retail sector (Cura, Jain, and Niinimäki 2022; Stenzel and Waichman 2023).

2.4. Blockchain

In recent years, BC has gained significant attention for being an effective tool for tracing information along value chains and addressing the retail challenges mentioned above (Dong et al. 2023). BC can add significant value to businesses by providing secure transaction verification, reducing costs by eliminating intermediaries, and improving efficiency by minimizing delays (Nowiński and Kozma 2017). The growing importance of BC is reflected in its rapid rise in economic significance. While investment in BC reached $800 million in 2014-2015, its projected business value is expected to grow to $3.1 trillion by 2030 - comparable to the current GDP of the entire African continent (McKinsey 2016; Gartner 2022; Statista 2024).

2.4.1. Blockchain Characteristics

BC is characterized by its immutability, meaning that it cannot be changed once data is recorded. It operates on a decentralized model that removes the reliance on third-party intermediaries like banks. Transparency is ensured since transactions are securely recorded on a peer-to-peer network, which typically maintains an accessible and transparent ledger. Consensus and advanced encryption algorithms guarantee that data remains consistent and protected across the network (Capocasale, Gotta, and Perboli 2023; Tripathi, Ahad, and Casalino 2023). For this reason, BC is often referred to as distributed ledger technology (Hilary 2022). Furthermore, it enables rapid validation and permanent transaction recording, improving security and traceability. Users maintain pseudonymity through randomly generated addresses, while each transaction is linked to an unused previous one, enabling effective fraud detection and tracking through time-stamped, verifiable records (Capocasale, Gotta, and Perboli 2023; Tripathi, Ahad, and Casalino 2023).

2.4.2. Blockchain Workflow

BCs consist of sequentially linked data blocks. When a user initiates a transaction, it is sent to the network for validation, ensuring system integrity and security (Vaigandla et al. 2023). Once validated, the transaction is added to a new block, which is cryptographically linked to the previous block, forming an immutable chain. The first block, the genesis block, does not reference a predecessor (Tripathi, Ahad, and Casalino 2023; Vaigandla et al. 2023). Transactions are secured through digital signatures, with users generating signatures using their private keys, while public keys serve as verifiable addresses for verification. These mechanisms ensure the authenticity and immutability of transactions, strengthening BC security (Rajasekaran, Azees, and Al-Turjman 2022). Each block within a BC contains a header, which includes essential metadata like timestamps and cryptographic hashes linking it to previous blocks and a body that records verified transactions. These components together ensure transparency, security, and resistance to tampering (Dong et al. 2023).

2.4.3. Consensus Mechanism

Decisions in BCs are made through consensus mechanisms, which describe a process by which nodes in a BC network collectively verify transactions and determine the order in which they are recorded on the BC (Nagar and Manoharan 2022).

Proof-of-Work (PoW). In BC networks like Bitcoin, the PoW consensus mechanism relies on miners to perform complex computational puzzles to validate transactions and create new blocks, securing the network through energy-intensive competition (Nagar and Manoharan 2022).

Proof-of-Stake (PoS). PoS represents an alternative BC validation approach, where network participants secure the right to verify transactions by depositing and temporarily locking their cryptocurrency. Validator selection is weighted by the size of their financial stake, encouraging

network participants to maintain a significant, committed investment in the BC ecosystem. It is substantially less energy-intensive than PoW (Nguyen et al. 2019).

2.4.4. Other Technologies

Notably, other technologies have been extensively researched in the context of BCCT.

IoT. IoT is a network of physical devices equipped with sensors, communication technologies, and processing units that can interact with each other and online services. These interconnected "smart" devices enable real-time data exchange and remote monitoring in applications ranging from home automation to industrial systems and monitoring carbon emissions within SCs. IoT devices typically integrate sensors to collect data, communication transceivers to transmit information, and microcontrollers to process and manage interactions in real-time, enabling sophisticated, automated functionality across multiple industries (Fraga-Lamas et al. 2016; Lee and Chung 2011).

AI. AI adds intelligence to machines, enabling them to gather information, process complex data sets, and make autonomous decisions. While AI systems often require training, they can analyze and interpret data, such as carbon emissions, independently. When connected to IoT, AI processes data collected by IoT nodes and transfers it to cloud platforms for advanced analysis. The system then generates insights, makes decisions, and communicates processed results to specific users or devices within the network, creating a sophisticated, adaptive technology ecosystem (Fraga-Lamas, Lopes, and Fernández-Caramés 2021; Schuetz and Venkatesh 2020).

However, while both technologies offer the potential to complement emissions tracing, this study concentrates specifically on BC.

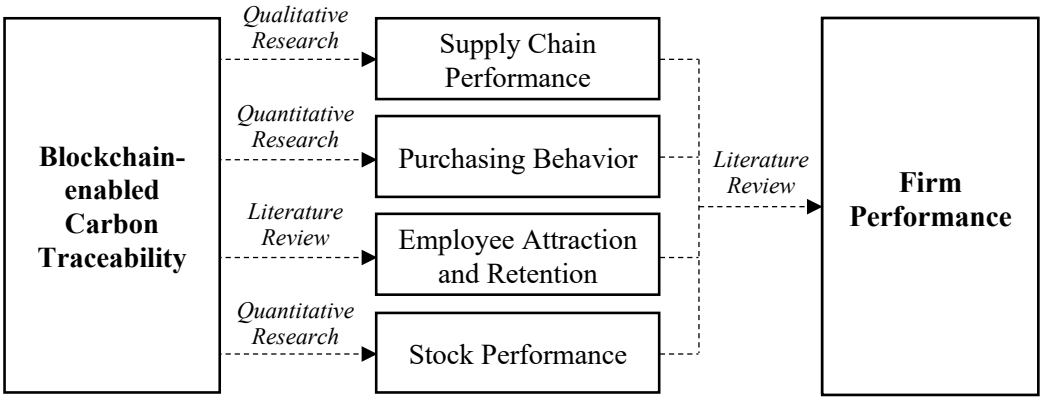
To summarize, BC’s core characteristics could be translated into an effective tool for tracing carbon emissions if the necessary information is uploaded by every player along the SC. Ultimately, this could support the development of a green SC by providing transparency from production to final

consumption (Zhao et al. 2022; Wang, Wang, and Abareshi 2020). Notably, the technical implementation is not within the scope of this thesis.

3. Methodology Overview for Individual Parts

To examine the impact of BCCT on retail performance in Europe, we analyze four key dimensions: SC performance, purchasing behavior, employee attraction and retention, and stock price performance. Finally, we evaluate how these dimensions individually and collectively impact firm performance using a mixed method, analyzing their relative impacts and potential synergistic relationships utilizing literature.

Figure 1. *Theoretical Framework.*



4. Summary of Findings of Other Individual Sections

This section highlights the key findings of the other individual sections of the collective thesis.

4.1. Supply Chain Performance

The findings reveal that BCCT enhances the four considered SC metrics: efficiency, transparency, trust, and sustainability. However, these effects rely on the presence of specific enablers identified in expert interviews, namely Supplier Education, Industry-wide Standardization, Integration with Complementary Technologies, and Long-term Supplier Relationships. Assuming these enablers

are in place, the enhanced SC metrics positively impact firm performance, with SC performance acting as a mediator.

4.2. Purchasing Behavior

Regarding purchasing behavior, BCCT does not currently appear to affect this variable, either directly or mediated by perceived transparency or consumer trust. Nevertheless, perceived transparency and trust independently drive purchase intentions, suggesting that consumer education and effective communication on the actual benefits of BCCT could narrow the gap between actual and perceived effects. This could eventually result in a positive impact on purchase intentions, which would, in turn, enhance firm performance.

4.3. Stock Price Performance

Furthermore, BCCT can positively impact a company's Environmental Pillar Score (EPS), which, in turn, shows a statistically significant positive relationship with stock prices over the past 15 years. By improving environmental valuation, BCCT may indirectly boost overall company performance.

5. Employee Attraction and Retention

Interest in the impact of BC technology on sustainability has grown consistently in recent years, with research emphasizing its beneficial effects on environmental outcomes (Park and Li 2021). At the same time, environmental responsibility has become increasingly important in organizational contexts. Yet, compared to external ones, its impact on internal stakeholders like employees remains underexplored. Research indicates that Green Human Resource Management positively impacts employee attitudes and behaviors, thereby enhancing overall organizational performance (Presley, Presley, and Blum 2018). Employees attaching more importance to non-financial outcomes, such as social responsibility and value for stakeholders, than to the company's economic

gains highlights this (Carmeli, Gilat, and Waldman 2007; Carmeli 2005). According to a Deloitte survey, around one-fifth of Gen Z and Millennial workers have shifted careers because of environmental issues, and more than 70% prioritize eco-friendly policies when searching for jobs (Clark 2024). In the modern knowledge economy, securing talent is essential for maintaining a competitive edge (Harsch and Festing 2020; Ma, Zhang, and Fang 2022). However, as demographic shifts and skills shortages increase the scarcity of qualified employees, especially in Europe, competition in the labor market - particularly for young talent - has intensified (Ackermann 2010; Gardner 2002). To stand out, companies must build strong employer reputations and environmental responsibility has become increasingly important to this appeal, which is confirmed by several studies (Williamson et al. 2010; Baum and Kabst 2013; Dögl and Holtbrügge 2014; Ma, Zhang, and Fang 2022; Perrini et al. 2011; Muisyo et al. 2022; Lievens and Highhouse 2003; Rupp et al. 2013). Establishing a relationship between a firm's environmental and firm performance can be complex, given the multitude of potential variables influencing both forms of performance. While there is growing research on the impact of BCCT on enhancing a firm's environmental responsibility (f.e., Adams, Kewell, and Parry 2018; Muzumdar, Modi, and Vyjayanthi 2022; Wang, Wang, and Abareshi 2020; Saberi et al. 2019) and substantial studies examining the effects of environmental responsibility on various employee behaviors (f.e., Dögl and Holtbrügge 2014; Muisyo et al. 2022; Cohen et al. 2017; Gully et al. 2013), the mediated relationship between BCCT and employee outcomes, particularly employee attraction and retention, remains underexplored. Therefore, this study aims to examine this link by exploring environmental responsibility as a mediator. Given this aim, the following RQ arises:

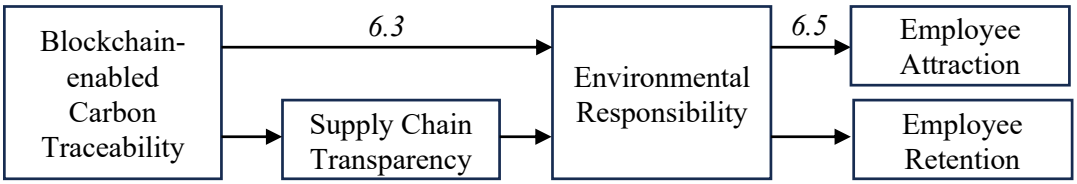
RQ_3: *Does BCCT impact employee attraction and retention for European retailers?*

To address RQ_3, we conduct a literature review to synthesize existing literature on this topic and to identify research gaps and potential areas for future research. This study contributes to existing research by bridging the gap between BCCT and employee outcomes, thereby offering insights into sustainability outcomes at an individual rather than organizational level.

5.1. Theoretical Framework

This section proposes a theoretical framework, displayed in Figure 2, to understand the complex relationships among BCCT, SC transparency, environmental responsibility, and employee attraction and retention. The independent variable in this model is BCCT, and the dependent variables are employee attraction and retention. SC transparency and environmental responsibility are explored as mediating variables in this relationship. As presented in Figure 2, we propose that BCCT impacts a company's environmental responsibility, partially mediated by its effect on SC transparency. This will be elaborated on in Section 5.3. Furthermore, we posit that environmental responsibility, in turn, impacts employee attraction and retention. While the underlying theories are explained in Section 5.4, the concrete relationships will be explored in Section 5.5.

Figure 2. *Conceptual Model of BCCT Impact on Employee Attraction and Retention.*



5.2. Effect of BCCT on Environmental Responsibility

The following section provides an overview of the effect of BCCT on a firm's environmental responsibility to pave the way for establishing the link between BC and employee attraction and retention. Section 5.2.1 explores the direct relationship between the two variables, while Section 5.2.2 explains how the relationship is partially mediated by SC transparency. Due to the

inconsistency in environmental measures in existing literature, we use a broad measure of environmental responsibility, which we define as a company's direct or indirect efforts to reduce environmental impact.

5.2.1. Direct Effect on Environmental Responsibility

Environmental sustainability in SCs depends on the efficient management of natural resources (Qorri, Gashi, and Kraslawski 2021). As mentioned in Section 4.1, BC technology supports SC sustainability by allowing real-time tracing of Scope 3 emissions throughout a product's lifecycle if BC principles (e.g., Textile Genesis) or energy-friendly BC mechanisms like PoS are used. This secure, accurate tracing of environmental data provides companies with a reliable system for monitoring sustainability targets and enforcing compliance with environmental standards. This aids in reducing carbon emissions through better-informed decision-making, as the main emitters can easily be identified (Adams, Kewell, and Parry 2018; Muzumdar, Modi, and Vyjayanthi 2022; Wang, Wang, and Abareshi 2020; Saberi et al. 2019).

Additionally, BC's ability to precisely trace each product's carbon footprint allows for more accurate assignment of carbon taxes, impacting product pricing. As higher-carbon products incur higher taxes and thus prices, consumers may be incentivized to choose lower-carbon alternatives. This mechanism inherently supports sustainability by penalizing higher carbon emissions and incentivizing companies to reduce emissions across their SCs to remain price-competitive (De Sousa Jabbour et al. 2019; Saberi et al. 2019; Széchenyi István University, Györ, Hungary et al. 2020).

BCCT further promotes sustainability by verifying the authenticity of green products, ensuring they meet environmental claims. With transparent tracing of production processes, BC enables consumers to trust green products, encouraging demand for genuinely sustainable options and

motivating companies to adopt lower-emission practices (Saberi et al. 2019). However, research on this provides mixed results, as no significant effect of BCCT on purchase intentions or trust is found in Section 4.2, suggesting that consumer education on BC is necessary for this effect to come into force.

In addition to these specific mechanisms, numerous studies have established that the general implementation of BC principles positively impacts a firm's overall sustainability (Park and Li 2021; Ezzi, Jarboui, and Mouakhar 2023).

5.2.2. Mediation through Supply Chain Transparency

As described in Section 4.1, BCCT enhances SC transparency, which is necessary for achieving sustainable SCs (Carter and Liane Easton 2011; Carter and Rogers 2008). The dynamic nature of business-environment interactions requires real-time, synchronized updates for all SC participants - an area where BC offers distinct advantages over traditional practices (Sarkis 2003). Transparency is the foundation for external control, reducing agency risks by minimizing information asymmetries (Lamming, Caldwell, and Harrison 2004). Therefore, each stakeholder can ensure that their upstream partners comply with environmental regulations. This collective accountability encourages the entire SC to actively work toward reducing its carbon emissions (Park and Li 2021). While greater transparency can lead to increased public scrutiny and pressure on a brand's SC, it also enables companies to leverage public oversight in addressing sustainability issues among suppliers. This approach not only supports improved SC sustainability but also helps mitigate potential brand damage (Shi Chen, Zhang, and Zhou 2019). Bastian and Zentes (2013) also demonstrate that increased SC transparency correlates with higher ecological performance across the SC.

5.3. Underlying Theories

This section explores the underlying theories to explain the effects of environmental responsibility on employee attraction and retention.

Signaling Theory. In competitive environments where organizations compete for scarce resources like talent, Signaling Theory helps to explain how companies convey information about otherwise unobservable attributes to shape the perceptions and decisions of key stakeholders (Turban and Greening 1997; Kooij et al. 2010). Since job applicants cannot directly observe a company's internal environment, they rely on signals, which are externally visible attributes, to infer aspects of workplace culture, values, and conditions (Rynes 1991; Breaugh 1992). The strength of these signals also plays a role. Strong signals, which are explicit and consistent, produce clearer, more positive interpretations, whereas weak signals leave more room for ambiguity and varied interpretations (Suazo, Martínez, and Sandoval 2011). Signaling Theory thus provides a valuable framework for understanding how companies shape perceptions among both prospective and current employees.

Social Identity Theory (SIT). SIT proposes that individuals identify in a social context and categorize themselves and others into social groups, including their workplace (Dutton, Dukerich, and Harquail 1994; Ashforth and Mael 1989; Tajfel and Turner 1985). Through social classification, individuals position themselves within their social context, fostering a sense of unity or belongingness with a broader collective (Stryker and Serpe 1982). This identification leads individuals to experience the group's achievements and setbacks as their own (Tolman 1943). The prestige of the group, including the employer, significantly shapes a person’s self-concept (Chatman, Bell, and Staw 1986; Dukerich et al. 2002). Individuals seek to enhance their self-concept through positive social comparisons, while negative comparisons can diminish self-esteem (Aberson, Healy, and Romero 2000; Ashforth and Mael 1989; Tajfel and Turner 1985). SIT is particularly relevant to this analysis because it highlights how employees derive self-esteem from

their employer's reputation, making sustainability initiatives a key driver of positive social identification.

Person-Organization (P-O) Fit. The concept of P-O fit is a significant factor driving organizational identification (Mael and Ashforth 1992). It suggests that individuals are most drawn to organizations with cultures that align with their values. Employees evaluate an organization's characteristics against their personal needs and values, and their perceived fit depends on how well these align (Kristof 1996; Chapman et al. 2005). While both SIT and P-O fit emphasize identification with organizations, SIT focuses on the broader social and self-esteem benefits derived from group membership, whereas P-O fit specifically addresses the alignment between individual values and organizational culture. Previous research supports the connection between P-O fit and job pursuit intentions (JPI), making it a useful framework for this section (Gully et al. 2013; Chapman et al. 2005; Muisyo et al. 2022).

5.4. Effect of Environmental Responsibility on Employee Attraction and Retention

The following section dives into how enhanced environmental responsibility, enabled by BCCT, impacts employee attraction and retention. Sections 5.4.1 and 5.4.2 explore the effect on attraction, and Sections 5.4.3 and 5.4.4 on retention. Notably, this section references studies with varying sustainability measures. This is reasonable as they collectively capture the multifaceted nature of environmental responsibility relevant to this analysis. Perception-based measures are particularly valid because employees' responses are often shaped more by how they perceive their employer's environmental efforts than by objective measures, as highlighted by Rupp et al. (2013). It can be inferred that actual environmental responsibility also enhances perceived sustainability, as research demonstrates that f.e., integrating environmental goals into corporate strategy enhances both actual and perceived sustainability (Turban and Greening 1997; Sharma 2000; Muisyo et al. 2022). Dögl

and Holtbrügge (2014) and Dewi (2020) further support this approach by showing that green technologies and initiatives, as well as environmental disclosure [1], significantly impact environmental reputation. Thus, despite their differences, the measures used in the cited papers align with the broader concept of environmental responsibility central to this study.

5.4.1. Effect of Environmental Responsibility on Employee Attraction

Existing literature suggests that a firm's environmental responsibility is positively related to employee attraction, which is "an attitude or expressed general positive affect toward an organization, particularly as a potential place of employment" (Chapman et al. 2005). In the literature explored in this section, related terms such as employer or company attractiveness, often referred to as employer reputation, and JPI are frequently used to describe various facets of candidate interest. While attractiveness and reputation represent passive, attitudinal reactions, JPI are more action-related (Chapman et al. 2005; Aiman-Smith, Bauer, and Cable 2001). However, as this thesis aims to explore actual outcomes for companies, we also take JPI into account for employee attraction, although they are not included in the traditional definition of attraction.

While many factors impact employee attraction, today's applicants increasingly prioritize intangible benefits, such as sustainability, over financial rewards alone (Dögl and Holtbrügge 2014; Muisyo et al. 2022; Perrini et al. 2011; Ma, Zhang, and Fang 2022; Posarajan 2018). Chapman et al. (2005) f.e., identify public image as one of the most influential factors in attracting employees. This shift is evident in another survey, where 93% of participants state that corporate reputation is important to them in assessing employer attractiveness (Hill and Knowlton 2008). Similarly, a study shows that a firm with market-average pay and career opportunities is more attractive if it

[1] BCCT falls under both, green technologies and initiatives and environmental disclosure.

has a positive social-environmental reputation than a company offering above-market pay but with a poor social-environmental reputation (Cohen et al. 2017). These findings align with those of Murray (2008), revealing that over one-third of respondents prefer to work for an employer with a good environmental reputation over one offering higher pay, while nearly 50% would decline to work for a company with a poor environmental reputation. These insights echo the renowned study by Turban and Greening (1997), confirming that the environmental dimension of corporate social performance enhances organizational reputation, regardless of its corporate performance. Multiple studies further support the impact of environmental responsibility on JPI and organizational attractiveness. Gully et al. (2013) show that recruitment messages emphasizing social environmental responsibility have a significant positive effect on organizational attraction and JPI. Likewise, Lis (2012), in a German sample, finds that the environmental dimension of corporate social responsibility (CSR) has a positive effect on organizational attractiveness. Similarly, Bauer and Aiman-Smith (1996) observe that a pro-environmental stance enhances perceived company attractiveness, JPI, and acceptance of a job offer. Further supporting these findings, Behrend, Baker, and Thompson (2009) show that pro-environmental messaging in recruiting positively impacts JPI, with a moderate effect size. The messaging also enhances perceptions of the organization's reputation. When both reputation and messaging are considered together, reputation shows a strong predictive effect on JPI, indicating that reputation is a key mediator in the relationship between environmental messaging and job interest. In line with these findings, Rupp et al. (2013) demonstrate a positive association between CSR[2] and the likelihood that prospective employees will pursue jobs with the company. This is further supported by Moorthy et al. (2017),

[2] Comprised of environmental and community relations.

who also find a link between the environmental dimension of CSR and JPI. In a comparable manner, a study by Grolleau, Mzoughi, and Pekovic (2012) demonstrates that companies with environmental standards are 47% more likely to attract professional employees than those without such standards. Moreover, many business leaders recognize that environmental reputation plays a critical role in attracting and retaining talent, especially highly skilled and educated employees with strong environmental values (Reinhardt 1999). Supporting this view, a survey of 1000 HR professionals shows that nearly half of employees prefer companies with a strong commitment to environmental practices (Phillips 2007).

5.4.2. Explanation of the Effect of Environmental Responsibility on Employee Attraction

Having established the link between environmental responsibility and employee attraction, the focus now shifts to understanding how this effect occurs. First, environmental responsibility fosters stronger relationships with stakeholders, including prospective employees. Companies committed to environmental responsibility gain loyalty, ultimately strengthening their reputation and making them more attractive (Rodrigues et al. 2023; Okafor, Adeleye, and Adusei 2021; Cohen et al. 2017). Additionally, environmental responsibility addresses applicants' inherent needs for predictability and stability by serving as heuristic cues. Job seekers interpret it as an indicator of fair treatment by an organization, which suggests that the company is likely to treat employees fairly as well, influencing JPI (van den Bos and Miedema 2000; Lind and van den Bos 2002; Rupp et al. 2013). This alignment between sustainability practices and perceived organizational fairness can be further understood through the lens of Signaling Theory, explaining that job seekers interpret environmental responsibility as a signal of broader organizational values and working conditions. Research suggests that a company’s social and environmental initiatives can serve as cues about workplace conditions (Greening and Turban 2000). When an organization demonstrates

environmental responsibility, job seekers may perceive it as indicative of a workplace that values employees and treats them with care and respect (Behrend, Baker, and Thompson 2009). Corporate green image, or similarly, environmental reputation, plays a significant role in this signaling process (Ahmad 2015; Ma, Zhang, and Fang 2022). It conveys two primary types of benefits to potential employees. First, it provides symbolic benefits by reflecting values such as environmental stewardship and prosocial behavior, aligning with the image of a high-quality employer (Alam and Islam 2021). Second, it offers functional benefits, such as assurance of sustainable development and environmental performance, suggesting stability, fairness, and a commitment to employee welfare (Jones, Willness, and Madey 2014; Bohlmann, Krumbholz, and Zacher 2018). These perceived benefits enhance job seekers' confidence in the company and increase their likelihood of pursuing employment there. Companies that lack direct involvement in environmentally friendly products or services can still demonstrate their commitment to sustainability by incorporating green technologies, such as using BC for carbon tracing (Dögl and Holtbrügge 2014). For job seekers, a strong environmental reputation provides even stronger signals about workplace quality compared to the current workforce, as they have less direct experience with the organization (Alniacik et al. 2011). Furthermore, as explained above, not only the content but also the strength of a signal influences its impact (Suazo, Martínez, and Sandoval 2011). Applied to carbon traceability, BC provides a more precise and transparent method and, therefore, a stronger signal than traditional, estimate-based projections. Various studies support the Signaling Theory as a valuable framework for explaining the relationship between sustainability and employee attraction (f.e., Lis 2012; Gully et al. 2013; Dögl and Holtbrügge 2014; Ma, Zhang, and Fang 2022; Turban and Greening 1997). Building on this, SIT offers another lens through which to understand the link between environmental responsibility and attraction. In the social context, job seekers may use an organization's environmental policies to signal their environmental responsibility to others,

leveraging the organization's values as evidence of their commitment (Cable and Turban 2003). Joining a firm with a strong environmental reputation allows individuals to enhance their self-image and project a socially responsible identity, which holds value in social interactions (Jones, Willness, and Madey 2014; Lievens and Highhouse 2003). Being associated with such an organization also enhances their social prestige, pride, and reputation, further increasing its appeal as an employer (Zhang, and Sun 2015; Xie, Bagozzi, and Meland 2015; Behrend, Baker, and Thompson 2009; Umrani et al. 2022). This social value motivates job seekers to pursue employment with companies that reinforce their desired identity (Opoku-Dakwa, Chen, and Rupp 2018; Liao and Cheng 2020; Lis 2012). The relationship between sustainability and employee attraction is further strengthened by P-O fit, particularly for individuals with strong environmental convictions. Research indicates that environmentally responsible organizations are particularly attractive to job seekers who prioritize sustainability, as these individuals perceive a stronger alignment between their personal values and the company's environmental commitments (Bohlmann, Krumbholz, and Zacher 2018; Gully et al. 2013; Muisyo et al. 2022). Therefore, companies with strong environmental reputations are better positioned to recruit and retain workers with strong personal environmental values (Reinhardt 1999).

5.4.3. Effect of Environmental Responsibility on Employee Retention

Environmental responsibility not only impacts employee attraction but also contributes to retention. Research shows that companies with a positive approach toward environmental responsibility are perceived as more desirable employers, not only for prospective candidates but also for their existing workforce (Bauer and Aiman-Smith 1996; Umrani et al. 2022). Furthermore, organizations that adopt green practices and implement pro-environmental initiatives benefit from enhanced corporate reputation, which helps retain top talent by fostering employee loyalty and

satisfaction (Esenyel 2020; Rodrigues et al. 2023). As Phillips (2007) notes, having a reputation as a green employer is increasingly recognized as a valuable strategy for retaining talent.

5.4.4. Explanation of the Effect of Environmental Responsibility on Employee Retention

Similarly to the effect on attraction, sustainability impacts retention through mechanisms like strengthened stakeholder relationships (Cohen et al. 2017). Employees who work for organizations actively addressing their social and environmental impacts are more likely to feel a sense of loyalty (Okafor, Adeleye, and Adusei 2021). Moreover, employees interpret their employer's sustainable practices as signals of a fair and supportive work environment, which increases their engagement and motivation (Suazo, Martínez, and Sandoval 2011; Rodrigues et al. 2023). This motivation enhances satisfaction, further contributing to retention (Dögl and Holtbrügge, 2014). However, as the information asymmetry between the current workforce and the employer is smaller than for prospective employees, the signaling effect here is smaller (Alniacik et al. 2011). SIT and P-O fit, as discussed in Section, also play a role in retention. Employees who perceive their organization as aligned with their environmental values and who derive social value from their affiliation with a sustainable employer are more likely to remain committed over time (Muisyo et al. 2022; Reinhardt 1999; Cable and Turban 2003; Li, Zhang, and Sun 2015).

5.5. Discussion

The findings suggest that BCCT contributes to environmental sustainability by enabling precise emissions tracing, real-time decision-making, accountability, compliance, accurate carbon pricing, and verification of green claims, with this effect partially mediated by SC transparency. However, based on the effect sizes from the papers used, the overall effect of BCCT on a company's environmental responsibility appears to be small to moderate. This may be due to the technology's reliance on widespread adoption, which requires stronger regulatory incentives to overcome high

implementation costs. The effect sizes may also be larger if all studies relied on energy-friendly BC mechanisms like PoS.

Furthermore, environmental responsibility attracts employees by signaling organizational values, strengthening corporate reputation, and addressing job seekers' needs for fairness, stability, and alignment with personal values. It also enhances their social identity and P-O fit, making environmentally responsible companies more appealing to prospective talent. Similarly, environmental responsibility enhances employee retention by fostering loyalty through strengthened stakeholder relationships, signaling a fair and supportive work environment, and aligning organizational values with employees' personal environmental convictions, boosting long-term commitment. Both of these effects are enabled through the same psychological mechanisms, namely Signaling Theory, SIT, and P-O fit. Considering the effect sizes in existing literature, the effects of environmental responsibility on employee attraction and retention seem to be small to moderate. It should also be noted that the effect sizes across studies vary. The use of different sustainability measures may explain this variation. Moreover, the relatively small effect size could be partly attributed to the predominantly psychological measures used in existing studies, which are difficult to quantify due to their subjective nature, variability across individuals, and reliance on self-reported data. Additionally, a perception-reality gap may influence the effect size, where employees and job seekers view environmental initiatives as superficial or as "greenwashing," diminishing their impact. Another possible explanation is that studies with smaller true effects are less likely to be published. This can create a bias in the published data, which can lead to an underestimation of the true effects (Riketta 2002). For retention specifically, the limited impact observed could be attributed to employees feeling that their daily roles have little influence on the company's environmental initiatives, which could diminish their sense of engagement and loyalty. Notably, while this study does not focus specifically on the retail industry, research

indicates that human resource practices are standardized across various industries, implying its applicability in retail (Edwards et al. 2016).

5.6. Conclusion

To answer RQ_3, the findings suggest that BCCT does impact employee attraction and retention in the European retail sector. However, the overall effect can be assumed to be small, as the individual effects of environmental responsibility on employee attraction and retention are already small to moderate, and the mediation is likely to further reduce the overall impact.

5.7. Limitations and Future Research

The following section discusses the limitations of this study and highlights directions for future research to further develop the insights presented.

Firstly, it is notable that this part of the thesis solely relies on existing literature. Therefore, the limitations underlying the reviewed literature also apply. One of these limitations is the general difficulty in measuring cognitions. Since these measures rely on (prospective) employees' subjective cognitions, they are afflicted with common psychological biases. For instance, employees may inflate positive responses in surveys about environmental responsibility because they seek to reinforce a favorable view of their organization, thereby enhancing their self-concept. Apart from that, a constraint exists due to the focus on a limited set of mediators, while it is likely that the relationships between the variables are embedded in an intricate web of variables. This makes it challenging to establish clear causal relationships. However, due to the scope of this work, a comprehensive examination of all mediators is not feasible, and the chosen mediators appear as the most prominent ones in current studies. Furthermore, the inconsistency in existing literature regarding the conception of environmental measures made it necessary to find a general sustainability measure that includes actual and perceived environmental responsibility. This may

oversimplify the construct, potentially reducing the precision and applicability of the findings. Additionally, the multitude of measures for both environmental responsibility and attraction and retention restrict quantifying the effect sizes for the relationships identified in the scope of this work. Without a meta-analysis, it is challenging to relate and compare the findings of studies that employ different metrics, hampering the ability to draw clear conclusions across studies. Moreover, the limited adoption of BCCT restricts the availability of firm-level data, resulting in a lack of studies examining its specific effects. As adoption increases, it may become possible to establish a more comprehensive link between BCCT and environmental responsibility, which is impossible now. The reliance on younger samples in many studies is another limitation. Research indicates that younger individuals are often more exposed to education and societal discussions around sustainability, which can influence their workplace preferences and intentions (Duarte, Gomes, and Neves 2014). This implies that the results may not be replicable for older populations, whose career priorities and exposure to sustainability-related topics may differ. Another point to consider is that some studies referenced are older despite the contemporary relevance of the topic. However, most of these studies are included because they are highly relevant to the analysis or necessary for establishing the foundational theories. Notably, a small portion of the studies considered in this research are conducted outside Europe, although the RQ focuses on European contexts. Moreover, the increasing globalization of environmental values among younger generations suggests that findings from non-European countries are also likely applicable (United Nations Development Programme 2016).

Future research should address the limited body of literature on BCCT's impact on environmental responsibility, as there is currently a lack of comprehensive studies on this topic. Moreover, studies should specifically examine the isolated effects of energy-efficient BC mechanisms, as these are likely to have a greater impact on environmental responsibility compared to traditional BC

technologies. Additionally, the disparity in literature volume between employee attraction and retention warrants further exploration to determine whether it reflects research priorities or inherent differences in these effects. Studies should also examine the perception-reality gap in environmental responsibility and its impact on employee behaviors, focusing on strategies to mitigate perceptions of greenwashing.

6. Impact on Firm Performance

After examining BCCT's impact on the four performance metrics - SC performance, purchasing behavior, employee attraction and retention, and stock price performance - this section evaluates their collective impact on overall firm performance.

Supply Chain Performance. Existing research consistently finds that superior SC performance significantly impacts the performance of retail firms (Tarigan, Jiputra, and Siagian 2021; Qrunfleh and Tarafdar 2014). Enhanced SC performance improves information flow, reduces inventory and operating costs, and increases on-time delivery, thereby improving firm performance (Zhang et al. 2006; Rai, Patnayakuni, and Seth 2006; Vonderembse et al. 2006). The four metrics used to measure SC performance underline this relationship. Research shows improved SC efficiency positively impacts firm performance (Daneshvar et al. 2020; Reiner and Hofmann 2006). In addition, SC sustainability has been linked to increased organizational performance, competitive advantage, and knowledge creation (Fabbe-Costes et al. 2014; Govindan et al. 2020; Baah and Jin 2019). SC transparency and improved information sharing positively correlate with operational performance (Bastian and Zentes 2013; Kim, Cavusgil, and Calantone 2006). In addition, SC and stakeholder trust have been found to contribute to improved financial performance (Baah, Acquah, and Ofori 2021; Salam 2017).

Purchasing Behavior. Purchasing behavior plays a pivotal role in driving firm performance. Most directly, purchasing behavior translates into increased sales revenue, which is a fundamental driver of firm performance (Kotler, Keller, and Opresnik 2017). It also serves as a key indicator of a firm's alignment with consumer expectations (Ijabadeniyi and Govender 2019). By analyzing purchasing data, firms can accurately predict the success of marketing campaigns and tailor strategies to maximize conversions and build long-term customer loyalty (Khaniwale 2015). This alignment not only strengthens customer relationships but also optimizes pricing and promotional strategies, ultimately enhancing market competitiveness (Griffith et al. 2009).

However, the findings in Section 4.2 suggest that BCCT alone is not a "magic bullet" for firms aiming to enhance consumer purchasing behavior and, consequently, firm performance. While BC offers features such as transparency and immutability, its impact on purchasing behavior depends on its integration within a consistent, educational, and credible communication strategy.

Employee Attraction and Retention. Existing literature agrees that the overall effect of employee attraction and retention on firm performance is positive. In the frame of Resource-based View, human resources, such as skilled employees and talented managers, are key assets that drive competitive advantages when they are valuable, rare, inimitable, and non-substitutable (Meyer 1991; Barney 1991). Attracting and retaining such talent strengthens a firm's unique capabilities, particularly in an increasingly skill-dependent global economy (Thurow 1992). More recent research further confirms the positive impact of talent management, including effective attraction and retention, on organizational performance. Regarding attraction, Davids, Button, and Bennett (2018) state that organizations that adopt a well-rounded talent acquisition strategy see improvements in overall performance. These improvements include greater productivity, higher sales, and better customer satisfaction. More generally, with the war for talent, attracting employees has become a challenge, and therefore, enhanced attraction should inherently result in an advantage

for the firm (Karunathilaka 2020). Relating to the effect of retention, numerous studies identify the negative impacts of employee turnover, which can be described as the rate at which employees depart an organization over a given period, voluntarily or involuntarily (Price 1977), therefore translating into a positive effect of retention. Hausknecht and Trevor (2011) demonstrate that collective employee turnover can result in negative consequences as it involves losing organization-specific human and social capital, disrupting operations and team dynamics, and driving up recruitment and hiring expenses. Moreover, employee turnover can heighten the risk of knowledge transfer to competitors since employees transition between organizations, potentially exposing key information, which may lead to a loss of market share and profits (Hancock et al. 2013).

Stock Price Performance. The stock price trend is a key indicator of a company's financial health, reflecting market valuation, growth potential, and investor confidence. Positive stock trends signal the firm's ability to generate sustainable profits, attracting institutional and retail investors while improving access to financing on favorable terms (Bird and Casavecchia 2007; Tang 2024). In addition to financial advantages, strong stock price performance facilitates operational improvements. Firms can allocate surplus capital toward research and development, SC optimization, and technological advancements that enhance efficiency and competitiveness (Brown, Fazzari, and Petersen 2009). Lower borrowing costs, driven by investor confidence, also improve cost structures and profit margins, enabling firms to reinvest savings into core operations (Aghion and Stein 2004). Positive stock trends further foster managerial confidence, encouraging long-term strategic planning over short-term profitability measures (Bond and Cummins 2004). This enables firms to pursue sustainable growth initiatives, such as expanding into new markets, ultimately enhancing long-term shareholder value (Aaker and Jacobson 1994).

Overall, all four metrics individually and collectively impact the shared dependent variable, firm performance, paving the way for implications aimed at optimizing outcomes of BCCT implementation.

7. Implications

Based on our findings, this section presents practical implications for European retailers. We synthesize these insights into five dimensions: Stakeholder education and training, stakeholder communication, stakeholder collaboration, operational deployment, and policy implications. See Figure 4 for a visualized overview.

7.1. Stakeholder Education and Training

Supplier Training. To successfully integrate BC technology into SCs, it is essential to ensure that suppliers are adequately trained and equipped to operate the technology effectively. Research highlights the importance of comprehensive training programs to enhance collaboration and problem-solving capabilities among SC partners (Manfredsson, Hilletofth, and Reitsma 2019). As emphasized in an industry expert interview, practical training could be implemented through regular webinars and structured meetings (I9). F.e., companies could host virtual workshops to walk suppliers through the process, ensuring they are well-prepared to integrate the technology into their operations.

Consumer Education. While supplier training is key to successful BC technology adoption, companies must also educate consumers to bridge the gap between technological complexity and consumer trust. The study results from Section 4.2 show that BC usage and the display of carbon data via the QR code do not currently provide the clarity consumers need. Therefore, educational initiatives are vital to improving consumer understanding of BC's role in enhancing data authenticity. As one industry expert states, "There's a need for more education on this topic, which

(should be) addressed through social media, advertisements, and websites" (I9). Without adequate understanding, consumers undervalue BC's role, limiting its ability to influence purchasing behavior (Duong et al. 2024). Educational efforts must focus on illustrating how BC technologies enhance traceability and reliability in ways that are relevant to consumers. Moreover, while BC enhances transparency, it also collects data that may raise concerns about personal information security (Ferreira Da Silva and Moro 2021). Therefore, implementing robust privacy protection is critical as privacy concerns remain a significant barrier to trust in BC technologies, hindering consumer confidence. Educational initiatives must demonstrate the balance between improved transparency and data privacy.

Employee Training. In parallel with supplier and consumer education, companies should introduce internal training programs to ensure their employees understand BC's functionality and its role in achieving sustainability goals. Without this internal awareness, the potential impact of BC technology - such as strengthening employee retention - may remain unrealized (Law, Hills, and Hau 2015). F.e., interactive e-learning modules could educate employees on how BCCT enhances transparency and supports carbon reduction, fostering a stronger connection to the company's environmental objectives (Draghici et al. 2021). Targeted training for marketing teams is also critical to enable them to effectively communicate BCCT sustainability benefits to consumers, as the empirical study in Section 4.2 highlights a lack of awareness in this area. For instance, a company could conduct workshops for marketing staff, focusing on creating campaigns that emphasize their dedication to trace the carbon emissions of their products accurately.

Investor Education. Finally, companies should address investor education to ensure that environmental initiatives gain recognition as drivers of long-term financial value. Despite the growing emphasis on sustainability, as shown in Section 4.3, industry expert interviews reveal that many investors still fail to incorporate environmental performance into their decision-making

processes. According to one industry expert, many investors rarely demand sustainability disclosures as a condition for financing (I1). Although our study positively linked EPS to stock price performance, this indicates a critical gap in further enhancing investors understanding. BCCT advantages can be educated most efficiently by showcasing measurable improvements in environmental performance, particularly as a tool to reduce carbon emissions, alongside tangible financial benefits, like cost savings and increased long-term returns (Strauß 2021). In addition, the positive impact of BCCT on environmental performance should be communicated to investors to ensure they are aware of the positive results. To address this, retailers implementing BCCT should proactively engage with investors through targeted communication strategies, such as sustainability-focused roadshows, investor briefings, and dedicated ESG reporting workshops. By showcasing how initiatives like BCCT improve EPS and financial results, companies can highlight the tangible benefits of environmental performance. Using case studies, data, and projections to link sustainability efforts to efficiencies, compliance, and risk reduction can shift investor perceptions. That helps investors see environmental initiatives as drivers of financial performance and shareholder value, not just tools for regulatory compliance.

7.2. Stakeholder Communication

Effective stakeholder communication is another critical lever for ensuring the successful implementation of BCCT.

Segmenting, Targeting, Positioning. Firstly, the results of the consumer study show that BCCT's effectiveness is not self-evident and depends on context-specific application and communication. As one industry expert explains, the effect "depends on how you are positioned as a company, what your focus market is" (I7), underscoring the importance of aligning BCCT with market segments, consumer needs, and niches. Market segmentation is critical, as not all consumers prioritize

detailed SC information. For instance, different generations prefer distinct sustainability communication approaches: Millennials with higher incomes and education gravitate towards clear carbon-related information, while Generation X relies more on traditional ecolabels (Balcombe et al. 2014; NYU Stern 2023). Retailers should customize marketing strategies accordingly - using tech-forward carbon labeling for younger consumers and familiar sustainability symbols for older demographics who may require educational support. Notably, BCCT also provides reliable environmental data that can serve as a foundation for enhancing the credibility of traditional labels preferred by older consumers. Furthermore, it is essential to use channels that resonate with the target demographic. F.e., it is particularly effective to communicate through social media for younger consumers, as 74% rely on these platforms for decision-making (Forbes 2017).

Positioning BCCT as a trust-building tool is also context-dependent. Research shows that displaying BC-enabled carbon information on a product is particularly effective for companies facing consumer trust deficits, as it can enhance credibility and transparency (Ma, Ma, and Hu 2024). However, for companies with high levels of existing trust, BCCT may add unnecessary complexity and risk alienating their audience. Thus, retailers must carefully assess their market positioning and focus audience to determine whether BCCT implementation will enhance or detract from their value proposition. In addition, retailers can assess the value of BCCT within their product portfolio and implement the technology for specific products where consumers value traceability.

Consumer Sustainability Communication. Secondly, consumers generally favor simple, relatable information over complex data. One industry expert notes that consumers "tend to focus more on (easy) labels, which are concepts everyone can understand" (I9). Overly technical information, such as BC-enabled carbon footprint labels, can overwhelm consumers and foster distrust in the technology (Rapezzi, Pizzi, and Marzocchi 2024; Treiblmaier and Gorbunov 2022) (I4). Instead of

showcasing which technology is used to determine the displayed carbon footprint - as done in the survey - simple sustainability labels should be used. This approach could help mitigate the risk of negative perceptions associated with BC.

Sustainability labels are an effective tool for boosting consumer confidence by simplifying the assessment of sustainability information, complemented by the QR Code and numeric footprint on the packaging. However, they must be clear, relevant, and seamlessly integrated into decision-making processes (Iraldo, Griesshammer, and Kahlenborn 2020). For maximum effectiveness, carbon footprint labels should combine categorical, color-coded, and numeric formats, as proposed by Lemken, Zühlsdorf, and Spiller (2021). We recommend stoplight-style labels enabling quick, intuitive comparison (Figure 3). This could help retailers enhance BCCT engagement - and encourage low-carbon choices (Andrews et al. 2014; Holenweger, Stöckli, and Brügger 2023). The QR code should then direct interested users to a clean, easy-to-navigate interface that presents the more detailed carbon data in an accessible, intuitive, and engaging way. According to the Technology Acceptance Model, technology adoption is largely driven by ease of use (Davis, Bagozzi, and Warshaw 1989). A seamless experience can bridge the gap between quick, in-store decision-making and a deeper understanding of sustainability information, ultimately enhancing interaction and purchases.

In addition, consumer trust and perceived transparency are often more closely tied to brand image and effective communication than to specific technological solutions like BC (Foxall, Oliveira-Castro, and Porto 2021). Therefore, storytelling could be a transformative tool in influencing consumer behavior, as narratives help consumers connect with sustainability claims. Stories illustrating positive impacts can make the carbon data more relatable and emotionally engaging. One industry expert stresses consumers need “other evidence to show why the data is trustworthy - maybe a success story” (I5). These should include retailers’ commitment to accurately and

transparently inform consumers and back this up with stories that personalize the sustainability journey and emotionalize the topic (Navas et al. 2021; Ospital et al. 2023). Similarly, storytelling could enhance employee attraction by strengthening the company's reputation.

In the long term, in contrast to our results from Section 4.2, BCCT could then serve as a stimulus for ensuring transparency and fostering complete consumer trust, provided it is supported by effective communication, education, and increased consumer awareness, as these elements align with the technology's capabilities.

Consumer Incentives and Engagement. Thirdly, reward systems and gamification can further enhance the effectiveness of BCCT on purchasing behavior by motivating consumers to make sustainable choices and improving their in-store experience. For instance, QR codes could display cumulative carbon savings, providing a sense of achievement and encouraging more profound engagement. Consumers increasingly seek interactive and immersive retail experiences and respond positively to innovative tools, such as BCCT (Savastano, Barnabei, and Ricotta 2016). Additionally, fostering community building through apps or platforms can create a collective sense of purpose among consumers. Such tools can promote shared sustainability goals, encouraging deeper engagement with the retailer and changing purchasing behaviors (Huang, Su, and Peng 2022). A notable example is Ben & Jerry's pilot program in London, which partnered with Poseidon to offer a platform allowing consumers to offset the carbon footprint of their purchases, combining BCCT with tangible incentives (Smith 2018).

Internal Sustainability Communication. Next, companies should regularly communicate progress on environmental sustainability goals internally to strengthen employee retention. As mentioned in Section 5.4, companies perceived as environmentally responsible benefit from enhanced loyalty and satisfaction among their workforce (Bauer and Aiman-Smith 1996; Rodrigues et al. 2023). Transparent and regular sustainability updates ensure that employees remain aware of their

organization's commitment to sustainability, reinforcing alignment with company values, fostering engagement, and bolstering retention through a shared purpose (Cohen et al. 2017; Suazo, Martínez, and Sandoval 2011; Muisyo et al. 2022). In line with P-O fit, this is particularly important for maintaining the loyalty of employees who derive social value from working for an organization aligning with their environmental convictions. Effective communication strategies could include creating dedicated sustainability updates during all-hands meetings, integrating progress reports into internal communication platforms like Slack or Microsoft Teams, or displaying real-time achievements on digital dashboards in shared office spaces.

Investor Sustainability Communication. Lastly, retailers should regularly communicate progress on environmental sustainability goals through external sustainability reporting to strengthen their appeal to investors. By transparently showcasing BC advancements in accurate carbon tracing, emission reductions, and other environmental performance metrics, companies can enhance investor confidence and reinforce their commitment to long-term sustainability (Jian-gang 2011). This communication should highlight measurable achievements, such as improvements in EPS or specific milestones reached through implementing BCCT. As mentioned in Section 4.3, transparent, consistent, and data-driven reporting can position the company as a leader in environmental responsibility, attracting sustainability-focused institutional investors and improving overall market valuation (Schiehll and Kolahgar 2024). Additionally, external communication efforts should be tailored to align with investor priorities, emphasizing financial and environmental outcomes to effectively demonstrate the value of sustainability initiatives in driving long-term growth and reducing risk.

7.3. Stakeholder Collaboration

In addition to communication, collaborating with external stakeholders is crucial.

Supplier Collaboration. First, the successful integration of BCCT into SCs requires the buy-in and collaboration of these partners, which must be secured through effective engagement by fostering long-term supplier relationships (I4, I5). In the next step, to encourage ongoing participation in the BCCT system, companies should emphasize the joint value of the implementation for suppliers and align the incentives of the cooperating organizations (Gutierrez et al. 2020). The former could be done, f.e., by referring to successful outcomes from pilot studies in the area, such as the one by Carrefour (Forde 2019). Another critical approach involves managing stakeholder relationships based on ethical principles and a commitment to addressing stakeholders' interests as ends in themselves rather than as means to an economic goal. Fairness, inclusivity, and long-term responsibility are key aspects of this approach (Kramer, Bitsch, and Hanf 2021). Such ethical stakeholder management could benefit from the transparency and accountability provided by BCCT, helping to build trust and to align partners around shared sustainability goals. F.e., companies could establish joint sustainability committees with supplier representatives to co-create carbon reduction strategies, ensuring all parties have a voice in decision-making and share in the benefits of the process. Similarly, transparent communication is also critical in securing supplier trust. Gutierrez et al. (2020) emphasize that creating a transparent communication and knowledge sharing culture can help build confidence in new processes. Our recommendation to achieve this is the formation of cross-functional teams with regular meetings to update company-external team members.

Third-Party Service Providers. Companies should also consider collaborating with third-party service providers, such as Aware or Textile Genesis, to overcome challenges such as high implementation costs and limited in-house expertise. These providers offer cost-effective solutions, reducing the need for significant upfront investment and simplifying the transition compared to in-house development. Their domain-specific expertise enables companies to optimize BC

implementations for energy efficiency, scalability, and security. By outsourcing these operations, companies can focus on core business activities, improving operational efficiency and strategic alignment without the burden of managing complex technical infrastructures. This approach is crucial in the short term, providing immediate solutions while companies can work towards longer-term internal BC development.

Industry-Wide Standardization. Moreover, according to industry experts, an industry-wide solution is essential for large-scale implementation of BCCT in retail (I1, I5, I7, I8, I9). One industry expert claims that "standardized data allows all stakeholders to work from a common platform, simplifying communication, decision-making, and goal alignment across the supply chain" (I2). To ensure this consistency and simplify emissions reporting, we recommend that retailers working with organizations such as GS1 (I7) establish common metrics and standards for carbon traceability. Standardization will reduce complexity for suppliers and increase transparency for consumers (Ehrler et al. 2016). A strong example of this collaborative approach is the Aura Blockchain Consortium, where luxury industry leaders Prada, Cartier, and Louis Vuitton partnered as competitors to develop a BC-based solution for shared challenges like transparency and traceability (Aura Consortium 2022). By opening the platform to all luxury brands, they fostered collaboration and established a unified standard, demonstrating how industry-wide solutions can drive consistency and scale across a sector. These efforts would also be in line with broader EU objectives for harmonized sustainability reporting under initiatives such as the CSRD.

Legislative Advocacy and Lobbying. Finally, retailers could influence the broader policy landscape by actively participating in legislative advocacy and lobbying activities (Guy 2006). Partnering with influential interest groups, such as EuroCommerce and Independent Retail Europe, could amplify retailers' voices in EU decision-making processes. These efforts should prioritize pushing for EU-wide adoption of BCCT, further harmonizing sustainability standards, and establishing

financial incentives, such as tax breaks or subsidies for retailers implementing BCCT. Furthermore, we recommend that retailers, particularly those with more significant financial resources, focus on lobbying for increased support under frameworks such as the EGD and lobbying for clear regulatory guidance and removing barriers to BCCT adoption. These actions could help ensure that sustainability requirements are achievable and beneficial for businesses.

7.4. Operational Deployment

Beyond stakeholder collaboration, retailers should also address operational efficiency and technology integration.

Targeted Recruiting. To effectively leverage BCCT to strengthen their workforce, companies should adopt targeted recruitment strategies that align with sustainability goals and attract skilled talent (Shahrulnizam et al. 2024). One approach is to filter for candidates with strong environmental convictions during the recruitment process. Companies could include sustainability-focused questions in interviews or application forms and use scenario-based exercises to assess candidates' environmental values (Das and Dash 2023). F.e., applicants could be asked how they prioritize sustainability in decision-making processes. This would ensure that new hires' values align with the company's commitment to environmental responsibility, fostering long-term retention through enhanced P-O fit and SIT, as outlined in Section 5.4. However, this strategy is most effective for companies with well-established or widely perceived environmental responsibility, as employees' values must align with observable practices to have the intended effect (Daqar, Smoudy, and Constantinovits 2019). Furthermore, highlighting sustainability initiatives in recruiting practices is another strategy for attracting talent, as environmental responsibility has been shown to enhance employer attractiveness and JPI (Lis 2012; Behrend, Baker, and Thompson 2009). Companies could achieve this by prominently featuring sustainability initiatives, such as BCCT, on their

careers page or creating dedicated recruitment campaigns that showcase progress on carbon reduction goals (Presley, Presley, and Blum 2018). Alternatively, firms could host virtual sustainability webinars for potential candidates, outlining how the company integrates BCCT to meet environmental objectives. Complementing this approach, incorporating green recruitment strategies, such as virtual interviews to reduce travel-related emissions or using paperless application processes, further demonstrates the company's commitment to sustainability, appealing to environmentally conscious applicants (Kiruthigaa and Viswanathan 2014). This effect is particularly strong among younger generations, who are more likely to prioritize sustainability when selecting employers (Duarte, Gomes, and Neves 2014). To effectively engage younger job seekers, organizations should tailor their messaging to platforms heavily used by this demographic, such as LinkedIn and Indeed, by emphasizing environmental responsibility and related initiatives. Social media platforms like Instagram or TikTok can also serve as effective tools for outreach (Vetráková et al. 2018; Bradford 2018). F.e., short, visually engaging TikTok videos showcasing employees' involvement in sustainability projects or Instagram reels featuring green workplace initiatives could increase JPI among younger candidates. Moreover, attracting talent with the necessary BC expertise to effectively integrate and manage BCCT systems remains a challenge, as highlighted by an industry expert: "I realized that the world of BC is quite small, and the number of people that actually understand it is really small" (Ge et al. 2021) (I6). To address this, companies could adopt targeted recruiting initiatives specifically aimed at IT specialists and BC professionals, such as partnering with universities offering BC-related programs and sponsoring capstone projects or internships to engage students early in their careers. Participation in BC-focused industry events, such as hackathons or conferences, could also help identify skilled candidates while positioning the company as a leader in BC technology. Additionally, posting job openings on niche platforms such as Web3 Jobs or Cryptocurrency Jobs could increase visibility

among qualified professionals (Kazakova and Bertulite 2020; Bradel, Steininger, and Veit 2019). Offering competitive learning and development opportunities, such as certifications in advanced BC applications, could further enhance the organization's appeal to this limited talent pool.

Stock Options for Employees. To complement targeted recruitment strategies and enhance employee retention and engagement, retailers could introduce stock option programs tied to environmental and financial performance metrics. By offering employees a stake in the company's success through stock options, firms create a direct link between individual contributions, sustainability achievements, and financial rewards (Oyer and Schaefer 2005). These programs should align stock options with BCCT-driven key performance indicators, such as improvements in EPS, carbon footprint reductions, or other measurable sustainability targets, aligning employee efforts with both short-term operational objectives and long-term sustainability strategies (Ammel, Boyer-Davis, and Karki 2024). By tying compensation directly to sustainability and financial performance, firms can foster a sense of ownership and loyalty, strengthen their ability to attract top talent and reinforce their commitment to environmental innovation, ultimately driving improved employee engagement and retention (Felo et al. 2015).

EU Funding Opportunities. Beyond workforce considerations, companies should leverage external support to accelerate BCCT implementation, such as tapping into the EU's research and innovation funding programs, designed to accelerate the transition to a greener future. Initiatives like Horizon Europe support projects like the European Blockchain Services Infrastructure (EBSI) (European Commission 2024b). To this date, €347 million in EU funding has been allocated to BC-related research and innovation, underscoring its significance in meeting Europe's environmental and technological goals (European Commission 2022b). We recommend that retailers actively seek out these programmes and apply for funding to gain additional resources to implement BCCT.

Integration with Complementary Technologies. While funding supports BCCT implementation, its operational effectiveness can be further enhanced through the integration of complementary technologies. Combining BC with emerging solutions such as IoT, AI, and satellite systems can address existing challenges, like ensuring the upload of supplier data, particularly its accuracy. IoT sensors can autonomously collect real-time product data and automatically feed it to AI systems, which then calculate emissions directly. This approach potentially eliminates the need for traditional LCA tools, streamlining the entire process. In addition, satellite data can increase the accessibility of carbon data up to the agricultural level (I6). An interconnected ecosystem facilitated by Application Programming Interface integration would enable these technologies to work collaboratively, automating data collection, analysis, and decision-making (I6). Studies by Naranjo, Espinoza, and Vivar (2023) and Suji Priya et al. (2023) support this model, demonstrating that such technological integration improves efficiency, enhances data security, reduces fraud risks, and promotes greater operational transparency. However, BCCT adoption is already challenging long-established retail SC processes, and integrating additional technologies could further complicate this transformative journey.

Energy-efficient Solutions. While integrating BC with complementary technologies can enhance operational efficiency, energy considerations remain. As environmental measures mediate the relationship between BCCT, talent attraction and retention, and stock price performance, adopting energy-efficient solutions is essential to impact firm performance positively. To address this, Sedlmeir et al. (2020) argue that adopting alternative BC designs, such as the PoS mechanism instead of the energy-intensive PoW, can substantially mitigate BC's environmental concerns. Second, we recommend integrating edge and cloud computing to reduce the computational burden on BC nodes, improving energy efficiency without sacrificing performance (Goel et al. 2024). Third, by collaborating with third-party service providers, energy concerns related to BC can be

mitigated. Textile Genesis, f.e., leverages BC's core principles by implementing a secure, transparent, and immutable digital ledger that traces textile SCs, utilizing digital tokens generated at the material's origin to ensure traceability while avoiding energy-intensive PoW consensus mechanisms.

Piloting. Above all, piloting is essential before scaling up to ensure a smooth operational deployment of BCCT. Hoek (2019) confirms this by highlighting the importance of targeted BC pilots in SCs to evaluate feasibility, costs, and benefits, drawing lessons from early adopters in logistics, consumer products, and retail industries. As already mentioned, Walmart piloted BCCT with mangoes in the U.S. and pork in China, collaborating with IBM for technology implementation, also demonstrating the value of third-party providers (Tan et al. 2018; Sharma and Kumar 2021). Furthermore, we recommend that BCCT be trialed within regional SCs to reduce complexity and minimize the need for extensive process changes. Focusing on a specific product category could further simplify pilots while generating insights applicable to other segments. Lastly, stakeholder buy-in throughout this process is crucial, as mentioned above.

7.5. Policy Implications

While the primary focus of this study is on firm-level implications, we also highlight key governmental policy recommendations to support and accelerate BCCT adoption.

Consumer Awareness Campaigns. Policymakers should invest in nationwide consumer education initiatives to raise awareness of the environmental benefits of BCCT. An industry expert underscores this: “There's a need for more education on this topic, which we address… . But other actors, like the state, schools, and universities, also play a role in educating the public“ (I9). Governmental campaigns could be integrated into broader government sustainability efforts, such as those under the European Climate Pact, an EU initiative aimed at collective action toward

achieving a climate-neutral Europe by 2050. Additionally, governments could support creating engaging media content - such as documentaries, podcasts, or social media campaigns - showcasing real-world examples of how BCCT enhances transparency, which promotes sustainability in the retail sector and facilitates compliance.

Government Incentives. To accelerate the adoption and implementation of BCCT, policymakers should introduce targeted financial mechanisms designed to reduce entry barriers and drive performance improvements. F.e., subsidies could cover initial implementation costs to some extent (EEG 2023). Tax credits could be offered to companies that achieve verified emissions reductions using BCCT, encouraging uptake and sustainable performance improvements. These financial instruments would be aligned with broader EU decarbonization goals related to the EGD. These incentives should be conditional on compliance with standardized reporting frameworks and measurable decarbonization outcomes to maximize impact.

8. Conclusion

This thesis analyzes how BCCT impacts SC performance, purchasing behavior, employee attraction and retention, and stock price performance, ultimately contributing to overall firm performance in the European retail sector.

In response to the umbrella RQ, this thesis concludes that BCCT can positively impact the performance of European retailers. This impact is observed across four key areas: SC performance, purchasing behavior, employee attraction and retention, and stock price performance. However, the impact level depends on Stakeholder Education and Training, Stakeholder Communication, Stakeholder Collaboration, and Operational Deployment, as outlined in the preceding section. Additionally, we suggest two policy implications, recognizing that incentives from the public sector also play a crucial role in the success of BCCT.

This thesis contributes not only to a more comprehensive understanding of effective BCCT in the European retail sector but also supports alignment with EU mandates to ultimately become the world's first climate-neutral continent by 2050.

9. Limitations and Future Research

This section discusses the limitations of this thesis, addressing constraints in scope, methodology, and analysis that impact the comprehensiveness and generalizability of the findings.

Narrow Focus of Metrics. This thesis evaluates the impact of BCCT on four performance metrics. While this provides a comprehensive framework, the scope is naturally limited due to the size of our research group, consisting of only four members. Consequently, other potentially critical areas, such as innovation performance, are not directly addressed, even though they might offer valuable insights. To address this limitation, future research should incorporate further performance dimensions to provide a more holistic approach to understanding BCCT's impact on firms.

Use of Mediators. The analysis relies on mediated relationships to evaluate the impact of BCCT on stock price performance, consumer purchase intention, and talent attraction and retention. While this approach is widely accepted in academic research and supported by theoretical and empirical evidence, it does not establish direct causal links. Consequently, other unmeasured factors may influence the mediators. Future research could aim to isolate and directly measure these effects to enhance the robustness and conclusiveness of the findings.

Focus on Application of Technology. This thesis examines the application of BCCT in the retail sector; however, it does not delve into the technical development of BC systems, such as algorithms, coding structures, or smart contract design. Future research should address these technical aspects to uncover potential constraints and enhance the optimization of BCCT implementation.

Heterogeneity of Retailers. The recommendations are generalized to address challenges across the European retail sector but may not fully account for the specific needs of individual retailers. Even touched upon briefly, differences in company size, resource availability, technological infrastructure, and market positioning may affect the feasibility and effectiveness of these recommendations. Future research could focus on creating more tailored strategies that align with diverse organizational capabilities and market conditions.

Lack of Quantification of Performance Impact. Although this thesis evaluates the impact of BCCT across four key metrics, it does not include a quantitative assessment of firm performance. The analysis focuses on qualitative insights and theoretical frameworks, leaving the magnitude of the effects unmeasured, as this would exceed the scope of the thesis. This limitation restricts the ability to compare the benefits of BCCT adoption against its costs or to evaluate its return on investment in measurable terms. Future research should incorporate quantitative methods, such as cost-benefit analysis or performance metrics modeling, to provide a clearer picture of the tangible impacts of BCCT on firm performance.

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List of abbreviations

BC	Blockchain
BCCT	Blockchain-enabled Carbon Traceability
CSRD	Corporate Sustainability Reporting Directive
EGD	European Green Deal
EPS	Environmental Pillar Score
ESG	Environmental, Social, and Governance
GHG	Greenhouse gas
JPI	Job Pursuit Intentions
LCA	Life Cycle Assessment
MRV	Monitoring, Reporting, and Verification
P-O	Person-Organization
PoS	Proof-of-Stake
PoW	Proof-of-Work
RQ	Research Question
SC	Supply Chain
SIT	Social Identity Theory

Appendix

Figure 3. *Visualisation of Stoplight Implementation.*

Figure 4. *Visualization of Implications.*

Stakeholder Education and Training

- Supplier Training
- Consumer Education
- Employee Training
- Investor Education

Stakeholder Communication

- Segmenting, Targeting, Positioning
- Consumer Sustainability Communication
- Consumer Incentive Engagement
- Internal Sustainability Communication
- Investor Sustainability Communication

Stakeholder Collaboration

- Supplier Collaboration
- Collaborative Data Sharing
- Third-party Service Provider
- Industry-Wide Standardization
- Legislative Advocacy and Lobbying

Operational Deployment

- Targeted Recruitment
- Stock Options for Employees
- EU Funding Opportunities
- Integration with Complementary Technologies
- Energy-efficient Solutions
- Piloting

Policy Implications

- Consumer Awareness Campaigns
- Governmental Incentives