Disentangling Greenwashing Discourse: A Topic and Sentiment Analysis of Public Engagement on Twitter

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Abstract: Greenwashing—defined as the strategic misrepresentation of corporate environmental practices—has emerged as a focal point of critical discussion on social media platforms. In this study, discourse related to greenwashing on Twitter was analyzed to uncover key thematic structures, sentiment dynamics, and polarization patterns. A total of 308,075 tweets authored by 148,881 unique users between 1 January 2015 and 31 January 2023 were collected and subjected to topic modelling and sentiment analysis. Ten primary themes were identified: (1) Sustainability and Marketing, (2) Climate Change and Fossil Fuels, (3) International Summits and Activism, (4) The Green Deal, (5) Environmental, Social, and Governance (ESG) Investments, (6) Plastic Waste, (7) Fast Fashion, (8) The Automotive Industry, (9) Deforestation, and (10) Food and Agriculture. Sentiment analysis, conducted using the Valence Aware Dictionary and Sentiment Reasoner (VADER), revealed a predominantly critical tone across the dataset. Negative sentiment was detected in 35.54% of tweets, while only 12.86% conveyed a positive stance; the remaining 51.6% were classified as neutral. These findings underscore the pervasive skepticism towards corporate environmental claims and highlight the perceived dissonance between green marketing narratives and actual corporate behavior. Furthermore, the study illustrates how public sentiment clusters around specific themes, suggesting issue-based polarization in perceptions of environmental credibility. By integrating topic modelling with sentiment polarity analysis, this research offers an empirical framework for evaluating public discourse surrounding greenwashing. The insights derived may inform both corporate sustainability communication strategies and policy interventions aimed at fostering transparency and accountability. Overall, the evidence points to an urgent need for more authentic, verifiable, and ethically aligned environmental messaging to restore public trust in sustainability initiatives.

1. Introduction

The environment has long been a focal point of attention due to concerns about the ecological impacts of industrial production, distribution, and consumption, prompting extensive research and the development of environmentally friendly products (García-Salirrosas & Rondon-Eusebio, 2022; Lee, 2020; Nuryakin & Maryati, 2020). Many companies seek to improve their environmental image by showcasing their environmental efforts in order to gain a competitive advantage and reach environmentally-minded consumers through green marketing strategies; however, it is not always true that all statements about companies' green activities accurately reflect their actual environmental efforts and can therefore be referred to as "greenwashing" (De Freitas Netto et al., 2020; Gregory, 2021; Hang et al., 2022; Szabo & Webster, 2021). Since 1986, the term greenwashing has been attributed to American environmentalist Jay Westervelt, who pointed out that hotels were asking guests to reuse towels as part of an environmental strategy to save water, even though this strategy had no significant environmental impact (De Freitas Netto et al., 2020; Guo et al., 2018). Greenwashing was previously defined as a shift from the

company's main obligations to the positive disclosure of selected information that is intended to emphasize the positive aspects of the company's environmental and social activities and thus overshadow environmentally unfavorable facts about the company's activities (Du, 2015; Lyon & Maxwell, 2011). This phenomenon poses a problem not only for society but for organizations and brands themselves, as greenwashing can imperil their reputation and profitability as well (Santos et al., 2024; Szabo & Webster, 2021). Previous studies also designated greenwashing practices detrimental to organizations, including consumer perceptions of products and environmental impacts (Mangini et al., 2020; Tarabieh, 2021; Torelli et al., 2020). According to recently published studies, greenwashing is a current threat to company performance (Alyahia et al., 2024; Chen et al., 2019; Rahman & Reynolds, 2017). Other studies suggest that greenwashing also affects green brand associations - brand credibility (Akturan, 2018), green brand image (Chen et al., 2019; Ha, 2022;), and loyalty (Chen et al., 2018; Chen et al., 2019; Hameed et al., 2021;). Studies indicate that one of the tools to mitigate the greenwashing effect is green transparency and authenticity (Alyahia et al., 2024).

Consumers value transparent, traceable, and unadulterated information to support their decision-making process. A study by Nygaard & Silkoset (2023) highlights that providing consumers with identifiable, reliable, transparent, and tamper-resistant information concerning the product plays a crucial role in mitigating greenwashing perceived. Even though greenwashing can damage a company's reputation, many companies are still reluctant to use transparency (Modi & Zhao, 2021) and fair communication (Gatti et al., 2019; Vollero, 2022) in their CSR campaigns. At the same time, previous studies indicated that transparency benefits businesses across all industries in their efforts to be sustainable (Egels-Zandén et al., 2015). Beyond the hospitality industry (Alyahia et al., 2024; Chen et al., 2018; Rahman & Reynolds, 2017), fashion apparel (Modi & Zhao, 2021) and fossil fuel companies are frequently discussed in the context of consumers' sensitivity to receiving transparent information (Friedman & Campbell, 2023). Investigations and research indicated a pattern of greenwashing among fossil fuel companies employing advertising campaigns to distract from significant emissions while strategically framing online communication on climate and sustainability. Such companies are influenced by external factors, like financial performance and climate events, to sway public perception despite the reality, suggesting a pervasive use of greenwashing and the dissemination of ambiguous or obscure information across the industry (Friedman & Campbell, 2023; Li et al., 2022). Research across various sectors indicates that perceived greenwashing diminishes purchase intentions towards sustainable clothing with a certain level of social cynicism (Policarpo et al., 2023) and impacts guest trust in green hotels despite positive relationships between environmental concern, trust in sustainable brands, and purchasing behavior. However, green authenticity and transparency can mitigate the negative effects of greenwashing, enhancing patronage intentions toward environmentally friendly practices (Alyahia et al., 2024; Apaolaza et al., 2023). Currently, driven by environmental changes and a growing emphasis on sustainable development, consumers and the public are confronted with a substantial volume of asymmetric information, particularly regarding corporate sustainability, green and sustainable production, and promoted pro-environmental values or companies' ESG efforts that often lack a tangible connection to customer needs (Aksoy et al., 2022). Customers' vigilance of greenwashing makes it increasingly difficult for companies to gain the trust of customers who are skeptical of information about companies' environmental efforts and who lack confidence (Lopes et al., 2023; Pomering & Johnson, 2009; Szabo & Webster, 2021; Szilagyi et al., 2022). The malleability of consumer attitudes has shifted markedly over the past two decades. Consumers were formerly constrained by a lack of knowledge and information (Alba & Hutchinson, 2000; Parguel et al., 2015). However, growing awareness regarding not only environmental challenges such as climate change and preservation efforts, but also concerning sustainable marketing methods and production (Khattak, 2019; Peterson et al., 2021). Thus, marketers have difficulty convincing customers through green marketing and presenting themselves as green sellers (Akturan, 2018; Khandelwal et al., 2019; Qayyum et al., 2023). Customers are sensitive to environmental claims that promote only positive aspects of a firm's environmental performance or exaggerated non-transparent environmental claims (Qayyum et al., 2023; Yang et al., 2021).

Accordingly, it is precisely the pressure on transparency that is much more pronounced these days. Due to environmental changes and emphasis on sustainability, public initiatives and government directives are also increasing the preventative and control measures against the dissemination of misleading environmental or green claims (Carreño, 2023). The recent development of initiatives, including legislation in the European Union, is a shift leading to new institutional duties aimed at preventing and mitigating greenwashing (Carreño, 2023; Coen et al., 2022; Lafarre & Verhoeff, 2023). A 2023 study commissioned by the EU Commission analyzed approximately 230 eco-labeled products, finding that over half contained misleading environmental claims, while 40% displayed unverified labels such as 'eco-friendly,' 'green,' or 'environmentally friendly' (Vollero, 2022). Various studies examined the extent of greenwashing in company reports, where businesses present themselves as environmentally friendly despite lacking genuine sustainability efforts (Callery & Perkins, 2021). Von Flüe et al. (2024) add that such behavior can highly worsen greenwashing. Therefore, a global framework is essential to enhance ESG disclosure transparency, comparability, and simplicity, helping to mitigate greenwashing risks and support sustainable business practices (De Silva Lokuwaduge & De Silva, 2022). Besides, associated taxonomy regulation ratings based on ESG can serve as a greenwashing prevention tool (Horn, 2024). Identifying key areas of

greenwashing, where the public perceives information as non-transparent and deliberately complex, is crucial for policymakers in developing effective regulation frameworks. As a result, it is critical to monitor customer perceptions, as well as the buzz and word-of-mouth surrounding green values and greenwashing issues.

The literature review shows that previous studies often focus on investigating the perception of greenwashing (Abbas et al., 2018) and green brand equity (Qayyum et al., 2023), green consumer consumption (Yang et al., 2021; Zhang et al., 2018), harmful practices of green marketing (Akturan, 2018), greenwashing and negative word of mouth (Sajid et al., 2024), green brand loyalty, green engagement, and green trust (Zaid et al., 2024), primarily through surveying (Qayyum et al., 2023). However, studies in recent years have taken a broader view of greenwashing perceptions by examining social media discussions (Alperstein, 2022; Amin et al., 2022; Blazkova et al., 2023). Social network analysis is, therefore, the inception of this research. According to Mahalakshmi et al. (2024), society's daily usage of online social networks has become ubiquitous. Social networks are used for sharing information, videos, photos, and chatting between residents of certain destinations, tourists, travelers, consumers, and, for example, reviewers (Alaei et al., 2017). In 2022, more than 4.6 billion people use social networks, and predictions show that by 2027, approximately 6 billion people will be using social media, which means huge research potential in various fields (Dixon, 2024a). Given the vast amount of data and information that millions of people utilize both in-person and online, social media is an ideal platform for business studies (Nie et al., 2023; Pearce et al., 2019). Due to these facts, it is possible to conduct several studies and obtain results in both commercial and academic settings (Kvasničková Stanislavská et al., 2023; Rosenberg et al., 2023). If there are multiple social media platforms, X/Twitter may be the first to post information related to text the most (Ainin et al., 2020; Oliveira & Huertas, 2019; Polyzos et al., 2024). By 2024, the social media platform X/Twitter will have over 611 million active users (Dixon, 2024b). The importance of X/Twitter resides in gathering big real-time communication data (Hussain et al., 2021; Šálková et al., 2023). X/Twitter data analysis provides insights into discussed issues (Gaytan Camarillo et al., 2021; Hussain et al., 2021; Prieto Santamaría et al., 2022), sentiment analysis (Czeranowska et al., 2023; Guo et al., 2023; Hassan et al., 2022; Mahalakshmi et al., 2024), and identifying potential trends of discussions (Ghahremani & Amiri, 2023; Tran & Matsui, 2023; Wang et al., 2021). Since the data were collected before March 2023, the previous Twitter designation rather than X will be used in the research. X/Twitter is not just a platform for social interaction but also for emotional expression among individuals and companies (Polyzos et al., 2024; Wheatley & Vatnoey, 2020).

The research was thereby aimed at identifying relevant themes and related emotions in Twitter discussions concerning the keyword 'greenwashing'. Since the data were collected before March 2023, previous Twitter designation rather than X will be used in the research. Results of the research emphasize the importance of credible environmental communication at two levels: first, for policymakers focusing on greenwashing mitigation, as it is key for assessing public sentiment in specific and thematic areas; second, for marketers interested in evaluating public sentiment towards greenwashing claims within key topics of greenwashing discussions. The contribution of this research lies in identifying key topics discussed in connection with greenwashing and visualizing how these topics are clustered or polarized in the debates on Twitter during the observed period. Although there are already studies focused on social network analysis with a focus on stakeholder analysis in the context of greenwashing (Blazkova et al., 2023) and earlier research exploring greenwashing in the context of social movements and public discourse (Alperstein, 2022), this research aims to expand knowledge by providing a deeper analysis of sentiment in greenwashing discussions. We focus on identifying key topics linked to greenwashing and conducting a detailed sentiment analysis. We identify positive, negative, and neutral discussions on crucial associated areas, thus contributing to a broader understanding of the overall mood surrounding greenwashing debates.

The use of Twitter platform for this research was essential as it enabled extensive observation of public discourse due to its openness and the speed with which information is shared publicly. Its hashtag-based communication structure allows for organic clustering of topics, making it a suitable tool for identifying thematic patterns and emotional tones, even in debates on complex topics such as the term greenwashing, which we are investigating (Dixon, 2024a; Hussain et al., 2021;). The uniqueness of the research is also due to changes in 2023, when the Twitter API allowed researchers to access longitudinal data, which allowed for large-scale studies that are no longer easily feasible. Therefore, this research dataset is a unique look at perceptions of greenwashing during an era of open digital discourse.

2. Methodology

The data analysis was based on the extended SMAHR (Social Media Analysis based on Hashtag Research) framework (Pilař et al., 2021a), a standardized and methodologically validated approach specifically designed for the analysis of social media discourse. This framework has been consistently applied across a variety of research areas like the Green Deal (Balcarova et al., 2024), Corporate Social Responsibility (Kvasničková Stanislavská et al., 2023), Burnout Syndrome (Ježková Petrů et al., 2023), Work-life balance (Kuralová et al., 2024), Cultured Meat (Pilařová et al., 2022) and Healthy food (Pilař et al., 2021b). The process of analysis consisted of four steps, which are drawn in Figure 1.
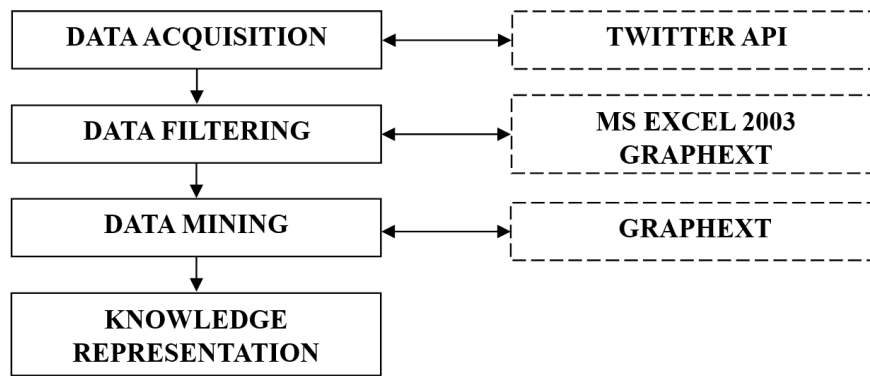
Figure 1. Steps of analysis

2.1 Data Acquisition

This step aimed to collect data on greenwashing from the Twitter database. The Twitter API v2 (X Developer Platform, 2015) was used to extract the tweets. The TRACTOR software was used to capture tweets from 1 January 2015 to 31 January 2023 based on the following query parameter: ["greenwashing" OR "#greenwashing" OR "green washing"]. These keywords were selected to ensure both terminological breadth and linguistic accuracy. They represent the most frequently used variations of the term "greenwashing" in both academic literature and social media discourse. By including the hashtag format as well as the spaced and unspaced textual forms, the query captured a wide range of relevant mentions while minimizing irrelevant noise. Based on this query, 308,075 tweets from 148,881 unique users were captured to the dataset. Twitter API v2 was selected due to its enhanced capabilities for structured access to historical tweet data, expanded filtering and expanded metadata availability over previous versions. Likewise, the TRACTOR software was chosen for validated performance in scalable data gathering, synchronous extraction, and dependable cohesion with the Twitter API. Combined, these tools enabled the inclusion of a response dataset that was both comprehensive and reliable.

2.2 Data Filtering

The aim of this phase is to ensure high integrity and relevance of the data that goes into the following phase 2.3 – Data mining. This process involves thorough filtering, examination, and analysis of the downloaded tweets (Pilař et al., 2021a). The basic steps in this process include A) verifying whether all tweets contain the keywords "greenwashing," "#greenwashing," or "green washing" to confirm that the relevant data had been accurately retrieved. B) Verifying the relevance of the message for users who create more than 50 messages per year. An example is the user "Biotipo", who published 568 completely identical messages. These messages were reduced to 1; otherwise, there would be a risk of creating a micro-community.

To address the presence of irrelevant or spam tweets, we applied the following explicit filtering criteria:
1. removal of exact duplicate tweets,
2. exclusion of repetitive content posted in bulk by the same user,
3. identification of bot-like accounts based on unnaturally high posting frequency and copy-pasted or template-based tweets.

As a result of the filtering process, approximately 1.2% of tweets were identified as duplicates or excessively repeated messages and were excluded from further analysis.

Despite the comprehensive nature of the research, the exploration indicated the absence of identifiable misleading or spam elements in the collected tweets. This outcome highlights the dataset's high quality and confirms its suitability for the subsequent stages of analysis.

2.3. Data Mining

This step aims to extract valuable and relevant information from the vast amounts of data generated by Twitter users (Pilař et al., 2021a). For this purpose, the following techniques were used:

2.3.1 Hashtag frequency
Hashtags fulfill two key functions in social media environments: (1) they identify particular topics with which the user aligns (marking their message accordingly) (Chang & Iyer, 2012; Pilař et al., 2021a); and (2) they enable users to highlight values, experiences, attitudes, and opinions within their posts (Childers et al., 2019; Pilař et al., 2021a; Zhang et al., 2020). The metric known as frequency indicates how often a given hashtag appears in the

network (Kvasničková Stanislavská et al., 2020). Hashtags were extracted from the entire dataset of tweets using the hashtag extractor software (Pilař et al., 2021a). Subsequently, their frequency was determined by using Gephi 0.9.2 software (Bastian et al., 2009).

2.3.2 Topic analysis

The goal of this section of the analysis was to explore the thematic structure of Twitter discussions surrounding greenwashing. By utilizing topic analysis, it becomes possible to uncover the primary themes or subjects present in large datasets, such as those generated from social media posts. Unlike frequency analysis, which primarily examines hashtags, this method analyzes entire tweets. Within complex social media networks, certain nodes, such as hashtags or words, are more tightly connected than others across the network. This clustering of hashtags and words facilitates the identification of distinct topics. This method provides a deeper insight into overall communication by revealing the relationships between individual hashtags and/or words.

Graphext software (Graphext, 2020) was employed for the topic analysis. To explore the community structure within the network, Graphext applied a modified version of the Louvain algorithm (Blondel et al., 2008). The network was constructed based on the interconnections among individual words contained in the tweets. Through an iterative process, the algorithm of Louvain assigns nodes to clusters in a manner that seeks to maximize a performance measure known as modularity. This measure compares the density of links within clusters to that between clusters. The number of distinct communities in the dataset was determined as follows:

$$\Delta Q = \left[\frac{\Sigma_{in} + 2k_{i,in}}{2m} - \left(\frac{\Sigma_{tot} + k_i}{2m} \right)^2 \right] - \left[\frac{\Sigma_{in}}{2m} - \left(\frac{\Sigma_{tot}}{2m} \right)^2 \right] \quad (1)$$

where, Σ_{in} corresponds to the cumulative sum of weighted links within the community, Σ_{tot} denotes the total weighted connections inside the community, k_i represents the total number of weighted links related to community hashtags, and $k_{i,in}$ is the total weighted linkages from an individual to community hashtags, and m serves as the factor of normalization, derived from the total weighted links across graph entire (Blondel et al., 2008).

2.3.3 Topic visual analysis

Network visualization techniques, such as force-directed layouts, can emphasize various network characteristics, including connection density and topic polarization (Pilař et al., 2021a). This part of the analysis aimed to determine the polarity of the topics that were identified. Graphext software (Graphext, 2020) was employed to conduct the visual topic analysis. A two-dimensional graph was generated using the ForceAtlas layout technique. Specifically, an improved version of the ForceAtlas algorithm, called ForceAtlas2, which focuses on massive networks, was used. This method leverages visual depictions of smaller samples to identify connections intercommunity within network communities (Jacomy et al., 2014).

2.3.4 Sentiment analysis

This phase of the analysis focused on identifying the sentiments expressed about greenwashing on Twitter. Sentiment analysis helps detect the emotions conveyed in tweets concerning a specific topic (Shamoi et al., 2022). This method classifies text as positive, negative, or neutral based on linguistic context and tone (Zucco et al., 2020). In the presented research, the VADER tool was employed for sentiment analysis. VADER is a lexicon- and rule-based instrument for sentiment assessment (Hutto & Gilbert, 2014).

2.4 Knowledge Representation

Knowledge representation serves as a crucial component of the data analysis workflow, allowing raw data and previous analytical results to be converted into forms that are both comprehensible and interpretable. This involves employing visualization techniques and tools that make it easier to present intricate information and outcomes to a wider audience. The overarching goal is to ensure that the findings are portrayed clearly and concisely, so they can be shared effectively and key insights can be emphasized (Pilař et al., 2021a).

This study used a combination of hashtag frequency analysis, topic analysis, topic visual analysis, and sentiment analysis. Hashtag frequency analysis revealed which key terms dominate the conversation, helping to identify the most discussed topics. Topic analysis uncovered the main themes related to greenwashing in Twitter discourse, while topic visual analysis focused on the polarity and interconnections between these themes. Advanced visualization techniques were used to interpret and present these relationships clearly. Sentiment analysis enabled the identification and classification of emotions expressed in tweets, offering deeper insight into public sentiment—whether positive, negative, or neutral—and highlighting areas of broad support or controversy. The integration of these analytical methods offers a comprehensive understanding of the dynamics and emotional tone of the discourse surrounding greenwashing on Twitter.

3. Results and Discussion

3.1 Hashtag Frequency

In this research, 308,075 Tweets from 148,881 unique users, including any word combination of greenwashing, were captured. Table 1 shows the most frequently used hashtags in the downloaded data set. The list comprises 26 hashtags that appeared in at least 1000 tweets associated with conversations about greenwashing on Twitter. The hashtag with the highest frequency of occurrence (86,530) is #greenwashing (1) when, at the same time, it is possible to mark several other hashtags in the list as synonyms. These are #stopfakegreen (9), #fightgreenwashing (24), or the German expression #nichtgrün (26). The multilingual and international resonance of hashtags indicating country-specific sensitivities was one of the most striking findings. The high frequency of this term in Germany corresponds to the highest number of legal actions against greenwashing within Europe. This suggests that public discourse is strongly tied to trust in institutions and pressure on regulation (Bladt et al., 2023; Hoffmann et al., 2023). Germany is ahead of all European countries in this regard when Hoffmann et al. (2023) state that there have already been several lawsuits dealing with greenwashing. A recent study states that the negative attitude towards the brand due to greenwashing among German customers is caused far more by false and untruthful information than bad environmental behavior (Bladt et al., 2023).

Table 1. The 26 most frequently used hashtags related to greenwashing on Twitter sorted by frequency

No.	Hashtag	Frequency	No.	Hashtag	Frequency
1	#greenwashing	86,530	14	#palmoil	1,707
2	#sustainability	5,970	15	#climateaction	1,691
3	#ESG	5,836	16	#sustainable	1,601
4	#climatechange	3,218	17	#boycott4wildlife	1,573
5	#climate	2,944	18	#RSE	1,557
6	#climatecrisis	2,937	19	#climateemergency	1,528
7	#green	2,879	20	#boycottpalmoil	1,338
8	#COP26	2,739	21	#taxonomie	1,330
9	#stopfakegreen	2,030	22	#netzero	1,264
10	#CSR	1,914	23	#COP21	1,244
11	#environment	1,793	24	#fightgreenwashing	1,063
12	#marketing	1,760	25	#fossilfuels	1,026
13	#killerpalm	1,719	26	#nichtgrün	1,009

The second most common hashtag is #sustainability (2), where several other terms indicating the same discourse can be found in the list - #green (7), #environment (11), #sustainable (16), and #netzero (22). Previous studies show that the business sector emphasizes complying with sustainable development standards, namely Social Development Goals (SDGs) (Bose & Khan, 2022; Kvasničková Stanislavská et al., 2023; Tsalis et al., 2020). Therefore, scholars must incorporate standard procedures for progressing toward a sustainable society (Demastus & Landrum, 2024).

The term #ESG (3) is also related to this category of "sustainable" hashtags. However, this one is more concrete, as it is directly oriented to the issue of responsible investments according to the ESG criteria of the concept introduced by the EU. When evaluating a company's sustainability performance, ESG reports are becoming increasingly important (Gutiérrez-Ponce, 2023; Hu et al., 2024). The increase in ESG report disclosure is mainly attributable to global capital market corporations. However, there are increasing instances involving greenwashing (Liu et al., 2024; Niu et al., 2024). One of the most notable and media-intensive global greenwashing scandals in 2020 was the DWS case (Cinceoglu & Strauß, 2024; Dempere et al., 2024). The content in ESG reports is often viewed with skepticism by investors (Dorfleitner & Utz, 2023; Oppong-Tawiah & Webster, 2023; Utz, 2017) Although these might appear as technical or industry-specific, their presence indicates a rising public skepticism towards sustainability claims in the financial sector. Discussions often highlight the risks of ESG funds being labeled "green" despite holding controversial assets, suggesting how even institutional investment vehicles are under scrutiny for greenwashing (Dorfleitner & Utz, 2023; Niu et al., 2024; Oppong-Tawiah & Webster, 2023; Utz, 2017).

Tweets on the topic of greenwashing also frequently use hashtags referring to the issue of climate change and the urge to deal with it - #climatechange (4), #climate (5), #climatecrisis (6), #climateaction (15), #climateemergency (19). This is not so surprising, as the coexistence of the "climate change" hashtags and the previously mentioned group of "sustainability" hashtags in tweets has also been found in previous studies (Kvasničková Stanislavská et al., 2023).

In eighth place was the hashtag #COP26, to which topics can also be assigned #COP21. This is because it is a designation of summits that were organized to solve the issue of climate change and sustainability. However, in both cases, they did not avoid criticism that it can lead to greenwashing and companies' mock behavior (Abudu et

al., 2024; Guinto et al., 2022).

The hashtag #CSR (10) and its French equivalent #RSE (18) are also associated with greenwashing on Twitter (Amin et al., 2022; Kvasničková Stanislavská et al., 2023; Oppong-Tawiah & Webster, 2023). The fact that some corporate social responsibility activities are labeled as such by the public is a common practice, as CSR activities are often their core marketing strategy (Moliner et al., 2019; Sanclemente-Téllez, 2017), as indicated by the hashtag #marketing (12).

Another group of tweets includes those drawing attention to the problem of deforestation or calling for a boycott of stakeholders associated with deforestation due to the expansion of oil palm plantations (Christiawan & Limaho, 2020; Schouten & Glasbergen, 2011; Van Tran et al., 2024). These tweets are interconnected with #killerpalm (13), #palmoil (14), #boycott4wildlife (17), and #boycottpalmoil (20). These hashtags indicate the fight against regular criticism of poor environmental and labor standards, as the sector and its representatives attempt to market their products as sustainable and highlight their efforts to help poverty, increasing public mistrust and suspicion of greenwashing (Kadandale et al., 2019). It is likely that the most frequently inclined regions are Indonesia and Malaysia, which account for 83 % of the world´s crude palm oil production in 2024, while the demand is still rising (Dauvergne, 2018; Limaho et al., 2022; Parsons et al., 2020). Indonesia's deforestation rate has increased drastically in the last 20 years, with a massive biodiversity loss and the loss of alarmingly endangered species while emitting vast amounts of greenhouse gases (Basyuni et al., 2018; Gaveau et al., 2022; Sheil et al., 2009; Sundaraja et al., 2021; Vijay et al., 2016).

In the list of the most frequently used hashtags associated with greenwashing, the terms #taxonomy (21) and #fossilfuels (25) remain to be mentioned. Taxonomy is often related to the European Green Deal and, as such, refers to a system of criteria and standards that help determine which economic activities can be considered truly "green" and, therefore, whether it is suitable or advantageous to support them (Hoepner & Schneider, 2022). Using the hashtag #fossilfuels in the context of greenwashing refers to labeling certain fuels as green when, in fact, they are not (Blazkova et al., 2023; Li et al., 2022). Research by Li et al. (2022) found that companies in the oil and gas industry, including Shell, ExxonMobil, BP, and TotalEnergies, have systematically used Twitter to obscure their actual involvement in the fossil fuel industry and distract from the transition to renewables. These findings suggest that greenwashing ads may play a key role in shaping positive attitudes towards these companies' environmental efforts, even though they may unrealistically highlight their efforts in this area (Friedman & Campbell, 2023).

## 3.2 Topic Analysis with Sentiment and Topic Visual Analysis

Topic analysis makes it possible to better understand the dynamics of the entire communication by identifying links between individual components of tweet content (hashtags, words, and phrases). The results of the topic analysis are shown in Table 2. This table includes the top 10 topics that deal with greenwashing on Twitter. The topics are sorted according to the absolute and relative frequency (%) of tweets that fall into the given topic. These extracted topics cover 73.68% (226,991) of all downloaded tweets.

Table 2. Identified topics related to greenwashing

No.	Topic	Size of the Topic		Key Terms
		%	**Absolut**	
1	Sustainability & Marketing	33.72	103,889	sustainability, green, marketing, product, consumer, company, eco, brand, claim, business
2	Climate & Fossil fuels	12.46	38,395	climate, carbon, fuel, fossil, oil, emission, gas, climate crisis, BP, climate change, big oil, offset, crisis, energy
3	Summits & Activism	6.83	21,056	cop26, cop21, France, protest, Greta, Paris, cop27, Thunberg, Greenpeace, government, action
4	Green Deal	4.98	15,342	Green Deal, EU, nuclear, gas, Europe, hydrogen, nuclear power, commission, deal, atom, greenwashing of nuclear power
5	ESG	4.23	13,025	ESG, fund, investor, investing, investment, bond, finance, risk, ESG funds, ESG investing, bank, sustainable investing, disclosure, rating
6	Plastic waste	3.14	9,678	plastic, coca, cola, recycle, recycling, plastique, Coca-Cola, waste, biodegradable, bag, recyclable, compostable, plastic waste
7	Fast fashion	2.76	8,491	fashion, beauty, brand, fashion brands, fashion industry, fast fashion, clothing, clothes, model, H&M, sustainable fashion, conscious, claim
8	Automotive industry	2.50	7,711	car, electric, energy, solar, renewable, Volkswagen, electric cars, Toyota, vehicle, diesel, hybrid, power, clean, emission, fuel
9	Deforestation	1.72	5,292	forest, tree, deforestation, wood, palm, palm oil, phantom, phantom forest, Ikea, forest logging, sustainable palm, deforestation business, wood consumption, reduce
10	Food & Agriculture	1.33	4,112	food industry, organic, meat, animal, agriculture, vegan, Monsanto, GMO, McDonalds, beef, smart agriculture, bogus food marketing
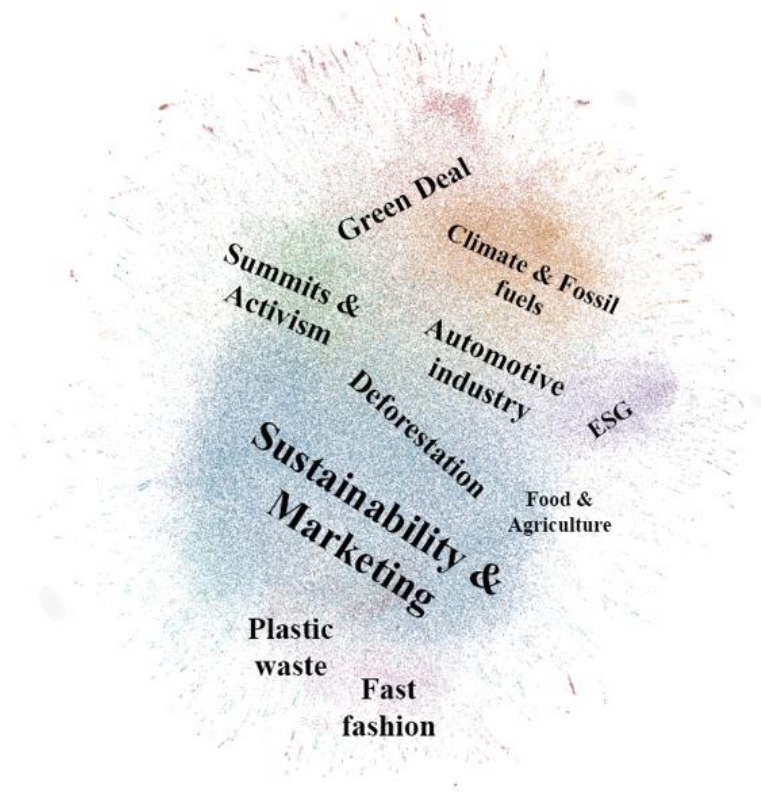
Figure 2. Topic visual analysis
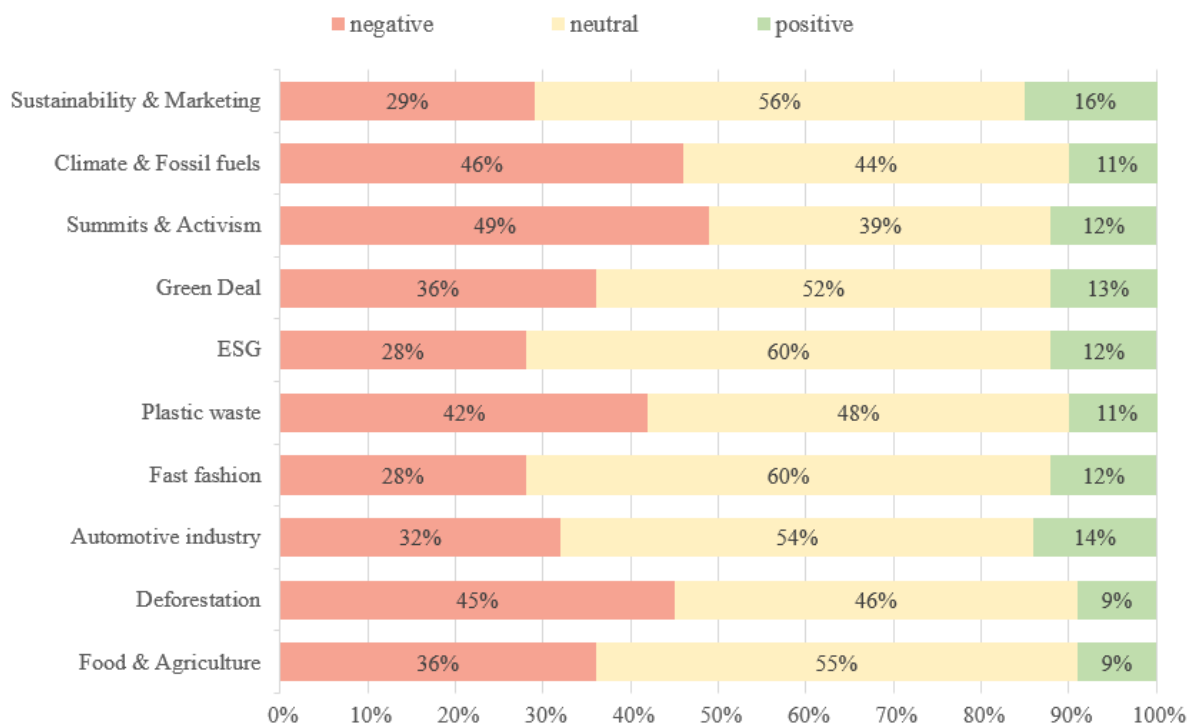
Figure 3. The percentage representation of individual sentiments in the extracted topics

The results of the topic visual analysis shown in Figure 2 aim to identify the mutual positions of individual topics. This allows us to determine their interconnectedness and/or polarization. The largest area covers the topic "Sustainability & Marketing", which is closely interconnected to the smaller topics "Plastic waste", "Fast fashion",

"Deforestation", and "Food & Agriculture". This is understandable because these smaller topics often discuss specific companies that included the concept of sustainability in their marketing activities, while their actual business activities were far from sustainable. Other topics are already more polarised. "Summits & Activism" is still partially intertwined with "Sustainability & Marketing," but it already forms a certain separator from the purely political topic of the "Green Deal". A similar situation can be observed in the "Automotive Industry", which forms a bridge to the more separate "Climate & Fossil fuels". Interestingly, discussions on "Climate & Fossil Fuels" are closer to political topics than to the discussions about marketing activities by specific companies. "ESG" lies somewhat aside, and it is most relative to the "Automotive Industry" and "Food & Agriculture."

The sentiment analysis sorts the opinions and attitudes expressed by users in tweets into three categories - positive, negative, or neutral sentiments. Overall, among all tweets in which the polarity was detected, negative sentiment prevails (35.54%), while only 12.86% were identified as positive. The majority of tweets without any polarized emotions (51.6%) were identified as neutral. This is not a surprise in the case of "greenwashing," as it is more of a derogatory label used as part of negative criticism of companies or political activities. However, persistent negativity can also erode trust not only in society but also in sustainability communication, including governmental or intergovernmental institutions (Lopes et al., 2023; Pomering & Johnson, 2009; Szabo & Webster, 2021). Furthermore, the prevalence of critical tones may foster a culture of green cynicism, in which consumers become desensitized or indifferent to sustainability claims. This could paradoxically weaken the effectiveness of truly sustainable marketing and communication efforts, reducing public engagement over time (Apaolaza et al., 2023; Nygaard & Silkoset, 2023; Policarpo et al., 2023;). The results of the sentiment analysis at the level of the ten main identified topics are shown in Figure 3. The highest representation of negative-sounding tweets is found within the topics "Summits & Activism" (49%), "Climate & Fossil Fuels" (46%), and "Deforestation" (45%).

The most extensive (No. 1) discussion (33.72% of tweets) concerns the issue of "Sustainability & Marketing" in the context of companies' marketing strategies, which is a topic that can be considered the essence of greenwashing - the discussion here mainly revolves around the fact that many companies adopt and communicate with their customers about the area of sustainability as part of their marketing (Jiménez-Marín et al., 2022; Lim, 2016). The topic visual analysis then confirms the interconnectedness and close position with strongly negative topics ("Plastic waste", "Deforestation") or "Fast fashion" and "Food & Agriculture", which by their nature and content are topics linked to the marketing performance of businesses across sectors. Customers are increasingly pro-environmentally aware, and their interest in and pressure on environmentally sustainable business performance is growing (Elshaer et al., 2024; Tran, 2024; Xie et al., 2019). In terms of sentiment, this topic is characterized by the highest percentage of positive emotions in the content (16%), with a higher neutral share (56%) and one of the most negligible negatives in the identified topics (29%). These results and the composition of key terms within the first topic correspond with previous studies confirming that customers perceive sustainable initiatives and their promotion as influential regarding brand loyalty and trust (Khan & Fatma, 2023; Nogueira et al., 2023). On the other hand, presenting non-existent or poor sustainability as 'green' is a new profitable marketing strategy of 'eco-opportunism' to attract green consumers (Nygaard, 2022; Nygaard & Silkoset, 2023). Many countries treat false, vague, or incomplete environmental claims legislatively. The parliamentary reading of the green claims directive in the EU is already underway, and the new instrument could enter into force there in the coming years, with experts estimating the period around 2026 (European Union, 2023). Under the proposed directive, businesses would have to adhere to a number of requirements regarding their assessment processes in order to support the voluntary green claims they make in their business-to-consumer commercial practices (European Parliament, 2024). The area of "Sustainability & Marketing" displays the most nuanced sentiment patterns, balancing between trust and cynicism (Nogueira et al., 2023; Nygaard, 2022;). These findings align with previous research that identifies Twitter as a fertile ground for expressing skepticism toward corporate sustainability claims (Amin et al., 2022; Blazkova et al., 2023).

The second topic discussed (No. 2 - 12.46%) is the area of "Climate & Fossil fuels." The adverse effects of fossil fuel consumption on the climate are generally a long-term debated topic. Fossil fuel giants, by emissions created by their products and processes, contribute to increasing greenhouse gases (Grasso, 2019), which is now alarming due to record highs of greenhouse gases reached in the atmosphere. Through the emissions created by their products and processes, these companies have significantly contributed to the increase in the concentration of greenhouse gases, especially carbon dioxide and methane, in the atmosphere and thus to anthropogenic climate change (Goodwin et al., 2015; Grasso, 2019). As studies confirm, these oil and gas companies significantly deny the consequences of climate change and the use of renewables through financing lobbying (George et al., 2016; Grasso, 2019) and are accused of greenwashing (Aronczyk et al., 2024; Berrêdo et al., 2024; Megura & Gunderson, 2022). In particular, the company British Petroleum (BP) has also become a confident "greenwashing standard" in the case of Twitter (Blazkova et al., 2023). Not surprisingly, they generate widespread social and political engagement (Grasso, 2019; Miller & Sorrell, 2014). This analysis confirms the public pressure and debate associated with negative emotions identified in 46% of the posts under "Climate & Fossil Fuels". The topic visual analysis delimits this topic in the upper right corner of the map connected with topics related to the "Green Deal", "ESG", and the "Automotive industry" with a common denominator in the form of emissions, energy, and

sustainable performance of companies. The identified predominant criticism of Climate & Fossil Fuels corresponds with earlier findings on public opposition to greenwashing by oil companies such as BP and ExxonMobil, mentioned above (Blazkova et al., 2023; Friedman & Campbell, 2023). However, our sentiment analysis quantifies this negativity and shows that it is among the most polarizing topics, highlighting the extent of public disillusionment.

The third theme, "Summits & Activism" (No. 3 – 6.83%), mainly includes discussions accompanying the climate change summits (e.g., COP26, COP21, COP27). These meetings of politicians often become the target of criticism and activism (Kythreotis et al., 2021; Santos et al., 2024), and activists are finding it progressively more difficult to see how the forward motion of the COP can be harnessed for a significant shift (De Moor, 2018). Even COPs generate movement, allowing for worldwide coordinated activism (De Moor, 2018; Harrebye, 2011); organizers of the COP have been criticized for having limited the speeches of protesters, as well as the places and timing of their statements in recent years (Tigue, 2023). Greta Thunberg's Fridays For Future (FFF) movement initiated a new upsurge of global climate action, initiated by her school strikes in 2018. As this occurs, younger generations, namely Generation Z, increasingly see social media as a battleground for which digital climate activism is significant (Belotti et al., 2022; Nisbett & Spaiser, 2023; Novak, 2024). At the center of the debates are the activities of the world's largest environmental NGO (non-governmental organization), Greenpeace (Zelko, 2017); not surprisingly, between the topics of "Green Deal", "Deforestation", and "Sustainability & Marketing". Its sentiment results represent the group with the most negative posts (49%) and relatively low neutral posts (39%), while only 12% are positive.

Another political topic, the "Green Deal" (No. 4 - 4.98%), can be described as the subject of critical discussions, but the emotions are neither significantly negative (36%) nor positive (13%). Neutral tweets predominate in this group (52%). The discourse concerns the effectiveness of European Commission regulations in connection with the EU Green Deal (Krämer, 2020; Oberthür & Von Homeyer, 2023). In the foreground are environmental issues associated with the "Green Deal", as confirmed by a Twitter sentiment study of the Green Deal (Balcarova et al., 2024). This topic addresses the unclear issue of gradually abandoning natural gas and oil consumption and the related transition to alternative energy sources (Balcarova et al., 2024; Jianhua, 2022). Nuclear energy's "green" role is also perceived as controversial (Imran et al., 2024; Pieńkowski, 2024; Tantau et al., 2022). "Green Deal" is a polarised topic located near "Climate & Fossil Fuels", "Summits & Activism", with a partial connection to the "Automotive Industry".

"ESG" (No. 5 - 4.23%) as a topic in this research-oriented mainly to the issue of responsible investments according to the ESG criteria of the concept introduced by the EU (Dorfleitner & Utz, 2023; Oppong-Tawiah & Webster, 2023; Utz, 2017). Topic ESG represents the highest proportion of neutral contributions (60%) compared to negative (28%) and positive (12%). It is also noticeably polarized compared to negative topics like "Summits & Activism" on the right. Companies and investors are increasingly adopting ESG criteria to make decisions and analyze companies with whom they will collaborate to assess the social and environmental impacts of trading and business, even if they are still not mandatory globally (Bofinger et al., 2022; Lian & Weng, 2024). The transparency of ESG information disclosure is thus currently critical when companies seek investors and other financing options (Yu et al., 2020). As a result, transparency is frequently discussed, and stakeholders are wary of corporations' potentially misguided sustainability information (Todaro & Torelli, 2024; Zhang, 2023) regarding potential greenwashing (Niu et al., 2024). However, this study advances prior work by offering a more nuanced analysis of sentiment across thematic clusters, which has been underexplored so far. For example, while previous studies often presented ESG-related discussions as neutral or driven by institutional discourse (Dorfleitner & Utz, 2023; Utz, 2017), our findings reveal that public responses are more emotionally charged and skeptical, reflecting distrust in ESG investments.

The following three topics bring the label of greenwashing back into connection with the activities of various business companies. "Plastic waste" (No. 6 -" 3.14%) is the fourth most negative topic (42%), near "Fast fashion" and "Sustainability & Marketing", making them a logical link to distribution within marketing. On Twitter, the issue of plastic waste production was particularly discussed, and the name Coca-Cola was often mentioned. Current challenges such as plastic pollution, packaging-related waste, deteriorating air, soil and water quality, climate change, and others affect the packaging industry. They may present barriers to implementing more sustainable packaging. However, consumer awareness of the benefits of sustainable packaging and its ability to reduce food waste is growing, driven by images of environmental pollution, mainly plastic waste in the oceans (Boz et al., 2020; Brennan et al., 2021; Haward, 2018; Mitchell, 2021; Nuojua et al., 2022). Coca-Cola, currently the world's plastic polluter, is most frequently mentioned in connection with plastic bottles and plastic waste despite promoting itself as a sustainable and environmentally conscious company (Cowger et al., 2024; Stanton et al., 2022). However, large global plastic waste polluters strive for sustainable performance and contribution to recycling, such as using plastic bottles for alternative purposes (Fakirov, 2021; Khurram et al., 2017).

The next topic is based on a specific fashion industry. This specific greenwashing topic is labeled "Fast fashion" (No. 7 - 2.76%). With the topic "Fast Fashion," it was surprising that this community is associated with a low value of negative emotions (28%), while there are neutral ones (60%) and positive ones (12%). As seen from the

topic visual analysis, it is in the middle and under all the topics, significantly separated from the others. Fast fashion was defined as today's swiftly accessible, low-priced fashion with a business model built on the concept of fashion being obsolete (Bhardwaj & Fairhurst, 2010; Bick et al., 2018; Diaz-Bustamante-Ventisca et al., 2024; Munir & Mohan, 2022). Many fast-fashion brands, such as H&M and Zara, have launched new sustainable communication campaigns that emphasize the availability of sustainable products but do not confirm the extent to which these companies' performance is sustainable (Diaz-Bustamante-Ventisca et al., 2024); H&M is considered a typical instance of greenwashing in sustainable fashion (Marko & Kusá, 2023). What appears to be a significant legislative development is that the European Commission launched the third set of measures (Directive on Green Claims) preventing greenwashing and false environmental claims, which covers the fashion industry as one of the most crucial areas where greenwashing is conducted (Balchandani et al., 2024; European Union, 2023).

"Automotive industry" (No. 8 - 2.50%) is a prominent example of a topic connected to a specific industry and causes. In the automotive industry, there has been progress in favor of electromobility, where in recent years, there have been cases of two automotive giants, namely Toyota and Volkswagen (Hickman, 2023; Moodaley & Telukdarie, 2023). Toyota cases companies denying global warming and the importance of electromobility in favor of internal combustion engines and fossil fuels (Dow, 2021; Otani & Yamada, 2017). The location on the topic visual analysis corresponds to the logical differentiation of greenwashing about waste and plastics. At the same time, it can be said that the "Automotive industry", although negative sentiment prevails (32%), has the second-highest share of positive sentiment (14%).

Deforestation is the third most negative (45%) topic of discussion (No. 9 - 1.72%). Although it is not the most significant and frequent topic, it lies at the center of the topic visual analysis of the relationships between the issues associated with greenwashing. The composition of the critical terms shows that there are two main areas. Firstly, deforestation is related to the expansion of palm plantations (Christiawan & Limaho, 2020; Schouten & Glasbergen, 2011; Van Tran et al., 2024). Secondly, timber extraction for processing and the furniture industry, where the Ikea brand resonates, and the causes associated with the extraction of protected forests (Montes-Sancho et al., 2022; Silva & Milcamps, 2023). However, there are other areas that are starting to be the subject of discussion. For example, phantom forests also mean a significant issue of greenwashing (Diaz Gonçalves & Saporiti Machado, 2023). The phenomenon of massive planting of new forests often means a greenwashing threat (Khadka, 2022). Such initiatives will fail due to inappropriate planting and the fact that such a forest will not survive, as there are no follow-up actions due to only promotional purposes (Bosshard et al., 2021).

The last topic included in the top 10 is "Food & Agriculture" (No. 10 - 1.33%), where greenwashing is discussed in relation to the field of agriculture and the food industry, as the main bearers of such signs are mostly labels and packaging (Montero-Navarro et al., 2021), organic food (Leblebici Kocer et al., 2023), and Genetically Modified Organisms (GMOs) (Francis, 2004). Despite society's opposition to GMOs, studies confirm that the widespread adoption of biofortification schemes is critical to achieving the lofty aim of eliminating malnutrition and hunger worldwide (Paarlberg et al., 2024; Sandhu et al., 2023; Sikora & Rzymski, 2021). The other greenwashing direction in "Food & Agriculture" is veganism, criticized as a fashion trend coaxing to "veganize" the mainstream (Bertuzzi, 2020) or specific companies such as McDonald's (Foley et al., 2024) and Monsanto are connected here with greenwashing activities (O'Connor, 2013). This topic prevails with 55% neutral emotions, 36% negative, and 9% positive emotions.

Overall, it can be stated that greenwashing does not only enter the final consumer category. Recent studies, corporate scandals, and accusations of greenwashing in multinational companies thus weaken the integrity of applied ESG (Hu et al., 2024). With ESG, it is evident from the results that the discussion revolves around sustainable investments and financial instruments far more than anyone would address, for example, the topics of carbon footprint, circular economy, waste management, packaging material, etc. Information is often considered vague and incomplete. Companies' skepticism towards the disclosure of ESG performance is thus growing. At least at the European Union level, Green Claims and CSRD could solve this problem (European Union, 2019).

4. Conclusions

This study provides a unique, large-scale view of how greenwashing is framed, challenged, and emotionally perceived by the public. By combining topic modeling with sentiment analysis and topic visualization, it offers a multidimensional lens for understanding how different sustainability narratives resonate — or clash — within digital public discourse. Among the most salient findings is the identification of highly polarized topics such as "Climate & Fossil Fuels" and "Deforestation," which reveal consistent public skepticism and emotional intensity. At the same time, nuanced topics like "Sustainability & Marketing" show more balanced sentiment dynamics, suggesting space for constructive engagement if transparency is maintained.

This study has delved into the discourse surrounding greenwashing on Twitter, uncovering hashtags, key themes, and sentiments from a substantial dataset of tweets. Our analysis revealed a predominant skepticism and critical stance among the public towards corporate environmental claims, emphasizing the importance of genuine and transparent communication from businesses. The identified topics, ranging from sustainability marketing to

climate change and corporate social responsibility, underscore the diverse facets of greenwashing discussions.

The findings highlight that while companies often engage in green marketing to attract eco-conscious consumers, these efforts are frequently met with distrust and criticism when not backed by authentic environmental practices. This skepticism is particularly pronounced in discussions about major industries such as fossil fuels, fashion, and automotive, where the gap between corporate claims and actual practices is most evident.

The analysis also revealed that the most frequently used hashtags associated with greenwashing were #sustainability, #ESG, and #climatechange. These hashtags indicate a strong public engagement with topics related to sustainability practices, ESG criteria, and the broader issue of climate change. This demonstrates that the conversation around greenwashing is deeply intertwined with critical environmental and social concerns.

Additionally, topic modeling identified ten major themes within the greenwashing discourse, including "Sustainability & Marketing", "Climate & Fossil Fuels", "Summits & Activism", "Green Deal", "ESG", "Plastic Waste", "Fast Fashion", "Automotive Industry", "Deforestation", and "Food & Agriculture". Sentiment analysis showed that approximately 35.54% of tweets were negative, 51.6% were neutral, and 12.86% were positive, with the highest negative sentiment observed in topics like "Summits & Activism" (49%), "Climate & Fossil Fuels" (46%), and "Deforestation" (45%). The topic visual analysis further highlighted the polarized nature of discussions, particularly around political and corporate initiatives.

For marketers and policymakers, these insights are crucial for developing strategies that enhance the credibility and effectiveness of environmental initiatives. Addressing the public's concerns and ensuring transparency can mitigate the negative impacts of greenwashing and foster trust in sustainable practices.

In the end, considering the results of the research, it is necessary to mention certain limitations of this study. In general, data from the social network Twitter may not fully represent wider public opinion or discussions on other platforms. The analysis is limited by the demographic biases inherent in Twitter's user base, which may not represent broader public opinion. Additionally, the self-selecting nature of users who engage with greenwashing topics can lead to over-representation of certain views or communities. Sentiment analysis tools may not be accurate with respect to sarcasm and irony. Lastly, Twitter's API limitations, such as access restrictions to older tweets and incomplete data streams, can impede comprehensive data collection, thereby affecting the robustness of the social network analysis.

Future research could explore cross-platform comparisons, stakeholder-specific discourse analysis (e.g., NGOs vs. corporations), or time-based evolution of sentiments and topics to further understand the dynamics of greenwashing narratives, including reactions to specific greenwashing events or policy changes. Moreover, qualitative case studies linked to specific hashtag clusters could help uncover how greenwashing scandals unfold in real time and how public sentiment escalates or transforms in response to events or policy shifts.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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