JMFS
Journal of Management and Financial Sciences

Volume XVI
•
Issue 53
pp. 103–119
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Perceptions of the circular economy: insights from Twitter

Abstract

This study investigates the evolving discourse on the circular economy (CE) on Twitter from 2015 to 2022. Leveraging sentiment analysis and keyword frequency tracking, we analyzed 513,709 tweets containing the hashtag #CircularEconomy. The study identifies prominent keywords, including *sustainability*, *recycling*, and *innovation*, and tracks their frequency over the years. Notably, c*ircular economy* reveals an overall neutral sentiment, gradually shifting towards positivity. We observe dynamic patterns in the discussion of the 3Rs (Reduce, Reuse, and Recycle), indicating varying emphases over time. The VADER sentiment scores underscore a nuanced shift towards positive sentiment. The findings contribute to understanding the public's engagement with CE concepts on social media and provide insights for further research and communication strategies.

Keywords: circular economy, Twitter, X, perception, sentiment analysis
JEL Classification: Q010

Introduction

On the 15th of September 2015, the General Assembly of the United Nations (UN) formally ratified the 17 Sustainable Development Goals (SDGs) [Dawes, 2022; United Nations Department of General Assembly and Conference Management, 2016]. These goals outline a global agenda targeted for realization by the year 2030, with a particular emphasis on sustainable and inclusive development for people and the planet. The circular economy (CE), an economic and industrial model that is restorative by intent and design, aligns closely with these SDGs [Ellen MacArthur Foundation, 2015]. It not only replaces the concept of waste with that of restoration but also seeks to decouple economic growth from the use of virgin resources, thereby contributing significantly to several SDGs [Cudecka-Purina et al., 2022; Di Maio, Rem, 2015; Ellen MacArthur Foundation, 2015; Ghisellini et al., 2016; United Nations, 2018]. According to the Ellen Macarthur Foundation [2013], a CE is defined as a system where the value of products, materials, and resources is maintained for as long as possible, minimizing waste generation. This concept is further elaborated by Geissdoerfer et al. [2017] as a regenerative system that minimizes input of resources, while reducing waste production, emissions of greenhouse gasses, and energy leaks by reducing, closing, or narrowing material and energy circuits.

Literature review

The *circular economy* (CE) is an economic and industrial model that is restorative by intent and design [Ellen MacArthur Foundation, 2015]. This model keeps the value of products, materials, and resources within the system for as long as possible, minimizing waste generation [Suikkanen, Nissinen, 2017]. The CE seeks to keep resources in use in economically viable ways, extracting maximum value during their use and recovering materials at the end of their useful life [Levillain, Matsumoto, 2017], in other words, this model keeps the value of products, materials, and resources within the system for as long as possible, minimizing waste generation.

With the rise of the CE social media platforms, especially Twitter, have played a pivotal role in promoting and disseminating knowledge about this concept. These platforms facilitate the building of communities, showcasing innovation, fostering collaboration, and advocating for the principles of the CE [Circular Economy Club, n.d.; Esposito et al., 2023; European Environment Agency, 2022; Marchesi, Tweed, 2021; Tsironis et al., 2022]. The wide reach of social media, its interactivity, and visual nature have proven effective in disseminating the CE concept to a broad audience, creating opportunities for education, engagement, and collective action [Esposito et al., 2023; European Environment Agency, 2022; Marchesi, Tweed, 2021; Tsironis et al., 2022].

Sentiment analysis on social media has emerged as a crucial tool in understanding public perception in recent decades [Lovera et al., 2021]. This process involves examining the language used in texts, such as social media posts or reviews, and categorizing it as positive, negative, or neutral [Qi, Shabrina, 2023]. Twitter, with its millions of users and tweets every day, has become a significant platform for the dissemination and discussion of climate-related and sustainability issues, including the CE [Carneiro et al., 2022]. Despite its biases and the disproportionate representation of societal views, Twitter serves as a proxy for public opinion and a platform for framing discourse on various topics [Górska et al., 2022; Vu et al., 2020]. Its significance in organizing collective actions [Chen et al., 2022; Segerberg, Bennett, 2011] and capturing users' knowledge and views on issues has attracted scholarly attention across disciplines [Pearce et al., 2019]. As a research tool, Twitter enables the identification and analysis of discourse patterns, behaviours, user sentiment, market movements, and health risks [de Andrade et al., 2020; Gloor et al., 2020; Zhang et al., 2011].

The primary objective of this research is to assess the perception of the CE discourse on Twitter (now X) from 2015 to 2022. We focused on English-language tweets and utilized Python, a powerful tool for data scraping and analysis, to ensure consistency and quality of the analysis. The data was meticulously cleaned, removing extraneous elements and organizing the text for comprehensive analysis. This research is guided by two main questions:

1. How has the sentiment surrounding the CE on Twitter evolved from 2015 to 2022?
2. What are the characteristics of this sentiment over the same period?

Through this analysis, we aim to provide insights into how the CE is perceived and discussed on Twitter, offering a unique perspective on public engagement with sustainability topics.

Methods

In this research, we aim to assess the perception of the circular economy (CE) discourse on Twitter from 2015 to 2022. A dataset comprising 513,709 tweets was analyzed, and 1,309,746 unique keywords along with their frequencies were extracted. The hashtag #CircularEconomy was used as the primary search term to retrieve relevant tweets.

The start of data collection in 2015 coincides with the publication of the Sustainable Development Goals (SDGs) by the United Nations [Dawes, 2022; United Nations Department of General Assembly and Conference Management, 2016]. This timeframe was chosen to capture the evolution of CE sentiment within the broader context of global sustainability discussions, influenced significantly by the SDGs. Sentiment analysis was conducted to identify the emotional tones and attitudes expressed in the tweets, providing insights into public perception.

For sentiment analysis, the Natural Language Toolkit (NLTK) library in Python was utilized. This library facilitated the quantification of sentiment scores, enabling a detailed examination of sentiment fluctuations over the seven-year period. Before analyzing the sentiment, irrelevant elements such as hyperlinks, special characters, and non-alphanumeric symbols were

removed during preprocessing. Standard natural language processing techniques, including tokenization and lemmatization, were applied to prepare the text for analysis [Khurana et al., 2023; Yogish et al., 2019]. This preprocessing transformed the unstructured textual data into a structured format suitable for sentiment analysis [Rai, Borah, 2021; Yogish et al., 2019].

The tweets sentiment analysis was classified into three categories: positive, negative, and neutral. This classification provided a detailed view of sentiment trends and a quantitative foundation for assessing changes in the sentiment over time.

Publicly available, de-identified data was used, ensuring the privacy and anonymity of Twitter users. Throughout the research, ethical practices were upheld to maintain the integrity and validity of our findings. This methodology was designed to investigate thoroughly the evolution and sentiment perception of CE discussions on Twitter, laying a solid groundwork for subsequent analysis and interpretation.

Words clusters

To enhance the visualization and analysis of our data, we focused on creating word clusters based on keywords relevant to the circular economy (CE). The literature identifies three core principles, commonly referred to as the 3Rs: Reduction, Reuse, and Recycling [Ghisellini et al., 2016; Lieder, Rashid, 2016; Winans et al., 2017]. These principles emphasize waste reduction, resource preservation [Dragomir, Dumitru, 2022], and the minimization of resource consumption, alongside reusing and recycling materials where possible [Ahmed et al., 2022; Ghisellini et al., 2016]. Detailed definitions of these principles are provided in Table 1, while Table 2 lists the refined keywords associated with each principle.

Table 1. Definitions of the 3Rs Model elements

Reduce
Definition 1. Aims to minimize the input of primary energy, raw materials, and waste through the improvement of efficiency in production (so called eco-efficiency) and consumption processes e.g. introducing better technologies or more compact and lightweight products, simplified packaging, more efficient household appliances, a simpler lifestyle, etc.
Definition 2. Involves reducing the input of primary energy and raw materials by enhancing production efficiency. Reduction refers to minimizing the input of primary energy and raw materials through the improvement of production efficiency.
Definition 3. The term *reduce* is used in three contexts: consumer-oriented, producer-oriented, or as a general term. It focuses on preventing waste production rather than managing waste after its creation and applies to all life cycle stages, including the use phase, although specific consumer actions during the use phase are not detailed.
Reuse
Definition 1. The Reuse principle refers to any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.
Definition 2. Encourages using by-products and waste from one firm as resources for other firms or industries and maximizing the use of products through regular maintenance and reclamation for extended durability.
Definition 3. Commonly refers to a product's second use, where it requires minimal adaptations and functions 'as new,' serving the same purpose without refurbishment, rework, or repair. This implies buying second-hand or selling lightly used products after cleaning or minor quality restorations by the consumer.

Recycle
Definition 1. Entails any recovery operation where waste materials are reprocessed into products, materials, or substances, either for their original purpose or other uses. This includes organic material reprocessing but excludes energy recovery and reprocessing into materials used as fuels or for backfilling.
Definition 2. Promotes the processing of recyclable materials into new products to reduce the consumption of virgin materials.
Definition 3. Involves processing mixed streams of post-consumer or post-producer waste using advanced technology, including shredding and melting, to extract (nearly) pure materials.

Source: own work based on Ghisellini et al. (2016), Reike et al. (2018), Su et al. (2013).

Table 2 illustrates the trimmed keywords associated with the 3Rs (Reduce, Reuse, and Recycle) based on their definitions within the circular economy framework.

Table 2. Trimmed 3Rs keywords

3Rs	*Keywords*
Reduce	reduction, reduce, reduced, reducing, minimize, efficiency, eco-efficiency, ecoefficiency
Reuse	reuse, reused, reusing, used again, same purpose
Recycle	recycle, recycled, recycling, recovery, reprocess, reprocessed, reprocessing, post-consumer, post-producer

Source: own work.

In our analysis, we initially distilled keywords and phrases, forming distinct clusters that align with each of the fundamental CE principles: Reduce, Reuse, and Recycle. Using Python, we implemented a classification methodology to categorize words extracted from the tweets, thereby gaining insights into prevailing sentiments and trends.

Our approach was not limited to simple word classification; it also encompassed the temporal dynamics of the 3Rs over the study period. We quantified the frequency of mentions for each principle, providing an enhanced understanding of their individual and collective trajectories. Furthermore, using the VADER sentiment analysis tool, we examined the sentiments associated with discussions about the 3Rs on an annual basis.

Results

Keywords evolution from 2015 to 2022

This study examines the evolution of discussions surrounding the circular economy (CE) on Twitter, focusing on a set of keywords associated with the term *circular economy*. Our analysis over the years from 2015 to 2022 reveals changes in priorities and focus within the global conversation about this concept. We identify engagement patterns and key themes in the Twitter discourse, offering insights into the most frequently used terms and their trends.

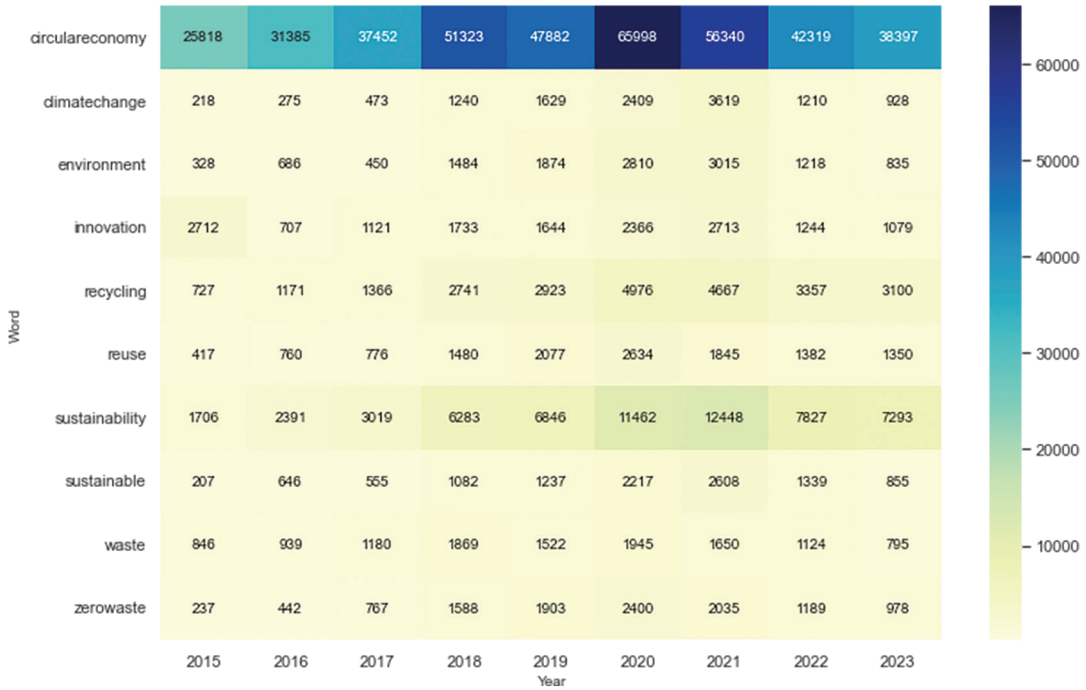
We analyzed the top 1,000 most frequent keywords from 1,309,746 unique terms collected over the study period (see Figure 1). A word cloud was created to visually represent these

keywords, showing the dominant topics and aiding further exploration of Twitter users' perceptions and priorities regarding the CE. This approach highlights a variety of viewpoints, with a focus on environmental awareness, technological advances, and societal responsibility in sustainable and circular practices.

Figure 1. Word cloud of the top 1,000 most frequent words associated with CE

Source: own work.

Figure 2. Top 10 most persistent words found across years



Source: own work.

Keywords such as *plastics*, *innovation*, *sustainability*, and *recycling* were prominent in the online conversations, demonstrating the breadth of topics discussed in relation to sustainable practices. Terms like *zero waste*, *environment*, and *climate change* indicate increasing engagement with important global issues. The inclusion of *start-up* and *SDG (Sustainable Development Goals)* suggests a link between CE discussions, entrepreneurial efforts, and global sustainability objectives.

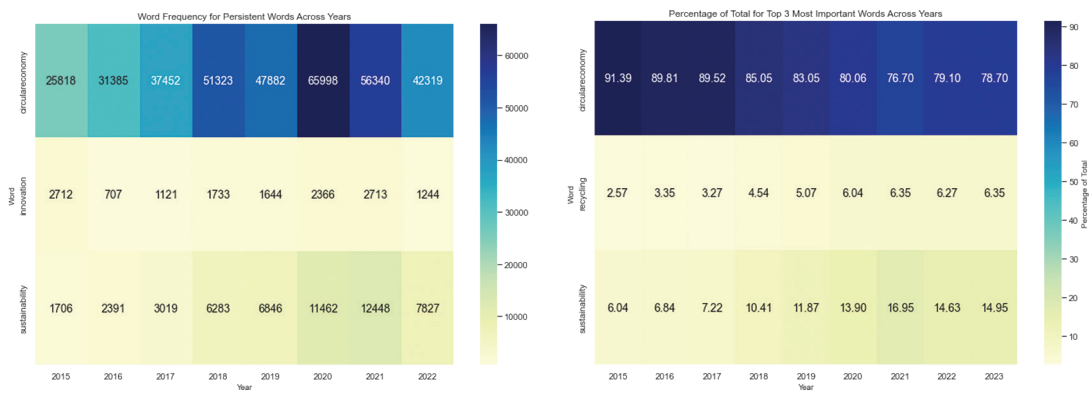
Our findings show changing patterns in word frequency related to the CE, sustainability, and recycling (see Figure 2). The term *circular economy* consistently appeared across the years and presented a steady growth in its utilization until 2020. While some terms showed stable growth, others fluctuated, reflecting changes in the nature of public discourse. A decrease in certain terms in 2022 prompts further investigation into the reasons behind these shifts. The continued presence of some keywords highlights their ongoing importance in discussions about sustainable practices and environmental awareness.

The word *sustainability* had an upward trend from 2016 to 2021, peaking at 12,458 mentions in 2021, but dropped slightly to 7,829 in 2022. This reduction might indicate a change in the focus of discussions or a temporary decrease in sustainability-related conversations.

The frequency of *recycling* varied over the years, with a notable increase from 2016 to 2021, peaking at 4,673 mentions in 2021, but then falling to 3,361 in 2022. This change could be linked to shifts in public discussions, events, or priorities. The term *innovation* consistently appeared throughout the years, showing a stable presence in the conversations.

The term *zero waste* gained popularity, especially from 2018 to 2021, reaching 2,036 mentions in 2021, but decreased to 1,905 in 2022. This dip might indicate a shift in focus or reevaluation of priorities. *Environment* and *climate change* consistently featured across the years, with their frequency peaking in 2021, indicating intensified discussions around environmental concerns during that year.

Figure 3. Word frequency and percentage of the most persistent words across years

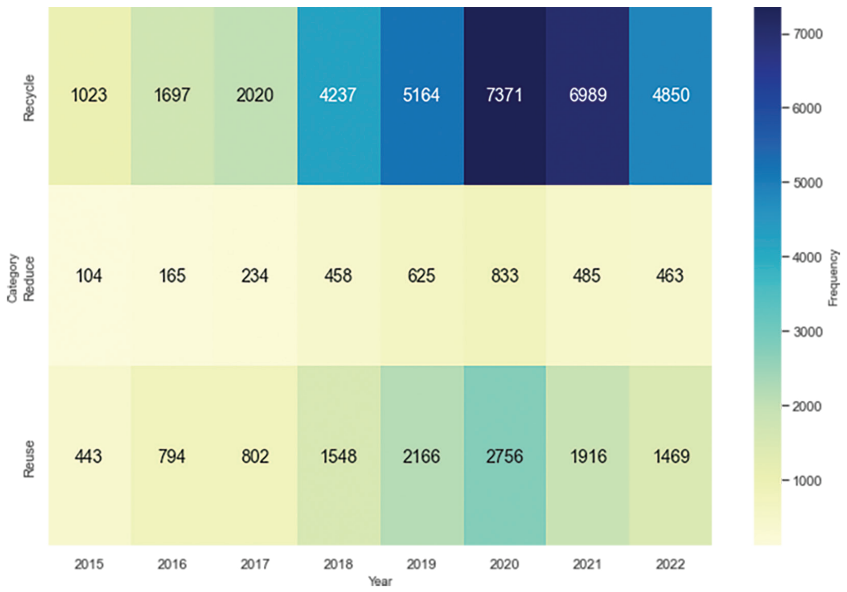


Source: own work.

The term *reuse* showed a fluctuating pattern, with peaks in 2021 and 2022, possibly reflecting a growing focus on reuse as part of broader sustainability efforts. *Business* and *innovation* were also frequently mentioned, highlighting the role of business and innovation in tackling sustainability challenges. The frequencies of these terms remained relatively stable.

In summary, our analysis of the keyword frequencies (see Figure 4) shows a significant and ongoing interest in CE practices, recycling, and sustainability. The terms *circular economy*, *recycling*, and *sustainability* showed increasing prominence over the years, with *circular economy* growing from 25,818 mentions in 2015 to 38,397 in 2023, peaking at 56,340 in 2021. *Recycling* had fluctuations in frequency, with a high of 7,277 mentions in 2015 and stabilizing at 3,100 in 2023. *Sustainability* consistently increased over the years, peaking at 12,448 in 2021. These trends indicate a growing commitment to environmentally conscious practices, with variations possibly influenced by global events, policy changes, or public awareness campaigns.

Figure 4. Word frequency by the 3Rs between 2015 and 2022



Source: own work.

In figure 5, our analysis shows changes in how the three Rs (Reduce, Reuse, Recycle) were discussed on Twitter over the years. These changes may be influenced by global events, shifts in public awareness, and changes in environmental priorities. More research into specific events or public campaigns during these years might help explain these trends.

The term *recycle* varied in frequency over the years. It was mentioned most in 2020, with 7,371 occurrences, followed by 2019 and 2021. However, there was a noticeable decrease in 2022. This pattern suggests that public attention to recycling practices changed over time. Among the three Rs, *recycle* was the most frequently mentioned in our study.

Reuse was the second most commonly mentioned term related to the three Rs. It gradually became more frequent from 2015 to 2020, indicating a growing focus on reusing items. However, there was a significant drop in its frequency in 2021. This could either be an anomaly or a shift in the discussion towards other CE aspects.

The term *reduce* showed varying levels of usage and was the least mentioned of the three Rs by Twitter users. It saw a noticeable increase in 2018 and 2019, which might reflect a rising awareness of the need to reduce consumption or waste. However, from 2020 onwards, there was a clear decline in mentions. This decrease could be due to a change in the focus of discussions about the CE or external factors like the COVID-19 pandemic.

VADER Sentiment scores analysis

The sentiment scores for the hashtag #CircularEconomy on Twitter, analyzed using the VADER tool, shows a primarily neutral sentiment with a gradual shift towards positivity from 2015 to 2021. The scores remained close to neutral, suggesting a balanced perspective towards the circular economy (CE) among Twitter users.

Table 3. Average sentiment score by year

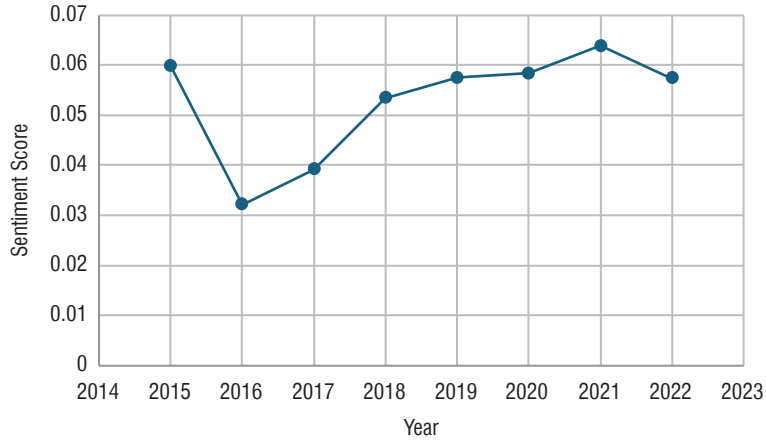
Year	Sentiment Score
2015	0.0598
2016	0.0321
2017	0.0391
2018	0.0534
2019	0.0575
2020	0.0583
2021	0.0638
2022	0.0573

Source: own work.

The gradual increase in positive sentiment scores indicates a growing but moderate interest towards the CE (see Table 3 and Figure 6). However, the overall neutral sentiment suggests diverse viewpoints and varying degrees of engagement with the concept among the Twitter community.

The sentiment analysis of tweets related to the CE hashtag categorized them into negative, neutral, and positive sentiments (see Table 4). A total of 18,372 tweets were classified as negative, indicating criticisms or reservations about the CE. The majority, 464,763 tweets, were neutral, neither endorsing nor opposing the concept. Positive sentiments were found in 30,574 tweets, showing support or enthusiasm for the CE.

Figure 5. VADER sentiment evolution through the years



Source: own work.

Table 4. Number of tweets that belong to each category

Sentiment	Count
Negative	18.372
Neutral	464.763
Positive	30.574
Total	513.709

Source: own work.

The distribution of sentiments reveals varied perspectives on the CE among Twitter users. While most tweets were neutral, a significant number expressed positive sentiments, suggesting a favourable view towards the concept. The presence of negative sentiments indicates areas for further investigation and understanding of concerns or critiques related to the CE.

Summary

The shift towards a more positive perception of the circular economy (CE) on Twitter not only reflects an evolution in societal attitudes but also underscores the impact of digital platforms in facilitating and amplifying public discourse on sustainability. This transformation is underpinned by several factors that contribute to an increased public consciousness about environmental issues. Social media platforms have become critical in disseminating knowledge about sustainable practices, thereby enhancing public awareness and education [Huang et al., 2021; Neff, Jemielniak, 2022]. These platforms serve not just as mediums for information exchange, but also as spaces for collective learning and advocacy, where users engage with and propagate sustainability narratives. This dynamic interaction between digital discourse and

societal attitudes suggests a symbiotic relationship where each influences the other, leading to a more informed and environmentally conscious public. As communities become more informed about the principles and potential benefits of circular economic models, the positive shift in the sentiment indicates a growing recognition of the role the CE can play in fostering environmental responsibility and sustainable development.

The analysis of Twitter discourse on the CE from 2015 to 2022 provides a granular view of how the public sentiment towards the CE evolved, highlighting the power of social media analytics as a research tool [Chen et al., 2022]. The methodology employed in this research not only allows for the examination of sentiment trends but also offers insights into the linguistic landscape of CE discourse, revealing how specific terms and concepts gain prominence within public discussions. This approach demonstrates the utility of digital platforms in gauging public interest and sentiment, offering valuable insights for policymakers, educators, and sustainability advocates.

The observed increase in the prominence of key terms associated with the CE, such as *circular economy*, *recycling*, and *sustainability*, signifies a broader shift in public discourse towards embracing sustainable economic models [Ganczewski, Jemielniak, 2022]. The growing engagement with the CE-related terminology on Twitter reflects an increasing public endorsement of sustainability principles [Geissdoerfer et al., 2017]. The CE represents a paradigm shift in how societies conceptualize and engage with economic and environmental sustainability. It is in line with the Ellen MacArthur Foundation observations [Ellen Macarthur Foundation, 2013; Ellen MacArthur Foundation, 2015], which highlight the pivotal role of the CE in contributing to Sustainable Development Goals (SDGs), emphasizing its regenerative nature and aim to minimize waste and resource consumption. The upward trends observed in the frequency of these terms reflect a growing societal awareness and commitment to sustainable economic practices, resonating with the goals of the CE and SDGs [Kirchherr et al., 2017; Mishra et al., 2023; Nikolaou et al., 2021; Rodríguez-Antón et al., 2022].

Our analysis illuminates the evolving perceptions and sentiments surrounding this crucial concept, underscoring the role of social media in shaping and reflecting societal attitudes towards sustainability. The observed trends in the discourse, characterized by a positive shift in sentiment and the increasing prominence of CE-related terms, reflect a growing public awareness and commitment to sustainable economic practices. This evolution in public discourse is supported by the academic literature that emphasizes the transformative potential of the CE in achieving environmental sustainability and aligning economic practices with the SDGs. The insights gained from this study contribute to a deeper understanding of the dynamics of public engagement with the CE on digital platforms, offering valuable perspectives for advancing sustainability agendas across various sectors.

Furthermore, the analysis delved into the usage patterns of the 3Rs (Reduce, Reuse, Recycle) within the CE discourse on Twitter. The literature emphasizes the importance of these principles in the CE, underlining the need to reduce waste generation, reuse materials, and recycle resources to minimize environmental impact [Arenibafo, 2023; King, 2022; Marques, Fritzen

Gomes, 2020; Sardianou et al., 2023]. The fluctuating patterns observed in the mentions of *recycling*, *reuse*, and *reduce* underscore the dynamic nature of discussions surrounding these principles. While *recycling* experienced peaks and dips over the years, *reuse* showed a growing focus, possibly indicating an increased emphasis on sustainable consumption patterns. The decline in *reduce* mentions on Twitter, highlighting potential gaps in the digital discourse around waste reduction, contrasts with the findings from Purwanto et al. [2023] about significant environmental awareness and the practical challenges in waste management by Halim et al. [2022]. Additionally, Harman and Yenikalaycı [2022] point to a gap where heightened awareness does not necessarily translate into practical knowledge or active discussions on platforms like Twitter. Almulhim [2022] further expands on this complexity by examining the household awareness and management of e-waste. In his study, the author addressed the lack of awareness about the hazardous materials contained in e-waste, the potential health and environmental impacts and the informal management of much of e-waste. These diverse findings underline the intricate relationship between awareness, intention, and online engagement, emphasizing the urgent need for nuanced educational strategies that bridge these gaps, fostering actionable behaviours and reflective discussions across both digital platforms and physical realms.

Additionally, the analysis uncovered shifts in the usage of associated terms such as *zero waste*, *environment*, and *climate change*, shedding light on emerging priorities and concerns within the CE discourse. The varying frequencies of these terms, coupled with sentiment analysis results, offer insights into the emotional tone and attitudes prevalent in Twitter discussions. Sentiment analysis, a powerful tool for understanding public perception, categorized tweets into negative, neutral, and positive sentiments, revealing a nuanced landscape of opinions and attitudes towards the CE. While a majority of tweets were classified as neutral, indicating a balanced stance, positive sentiments outnumbered negative ones, suggesting growing interest and enthusiasm for CE initiatives.

Overall, this analysis provides valuable insights into the evolution of the CE discourse on Twitter and its alignment with broader sustainability goals. By connecting the results with existing literature, we gain a deeper understanding of the societal perceptions and priorities driving discussions surrounding the CE. This will pave the way for informed policymaking and advocacy efforts in the pursuit of a more sustainable future.

The research findings influence significantly policymaking, educational efforts, and corporate strategies in sustainability, highlighting the value of continuously monitoring social media discourse, like the one on Twitter, for real-time public feedback on policy effectiveness. By analyzing sentiment trends and keyword usage, policymakers can assess and adjust their strategies to align better with public attitudes, ensuring that policy interventions resonate with the expectations of communities. This methodology extends to crafting targeted awareness campaigns in education, where insights into popular terms and concepts on social media can help tailor messages for greater engagement and impact. In the corporate realm, understanding public sentiment towards the CE can unveil opportunities for sustainability innovation,

allowing companies to leverage positive sentiments to enhance their brand reputation and align their sustainability efforts with stakeholder values, thus creating a cohesive strategy that addresses the priorities of policymakers, educators, and businesses alike in promoting sustainability and CE principles.

Our study's focus on English-language tweets may limit the generalizability of its findings to non-English-speaking communities. Future research could explore the circular economy (CE) discourse in other languages for a more comprehensive understanding of global perceptions. Additionally, the reliance on Twitter data alone may not capture the full spectrum of public opinion on the CE. Employing a mixed-methods or cross-sectional approach, combining social media analysis with surveys or interviews, could provide more nuanced insights.

While our study spanned from 2015 to 2022, future research could include more recent data to capture ongoing trends in the CE discourse. Moreover, while sentiment analysis offers valuable insights, it may not always capture accurately the nuances of human emotion and context. Exploring different sentiment analysis techniques could improve accuracy and reliability. Moreover, further research could focus on assessing the impact of the CE discourse on actual behaviour change and policy outcomes. Longitudinal studies tracking changes in public attitudes and behaviours over time could provide valuable insights into the effectiveness of sustainability initiatives.

In conclusion, our study provides a detailed examination of the perceptions surrounding the circular economy (CE) on Twitter from 2015 to 2022, leveraging a substantial dataset of English-language tweets to investigate the evolution of public sentiment and discourse. Our findings reveal a significant increase in the prominence of CE-related terminology, indicating a heightened public awareness and engagement with sustainability practices aligned with the United Nations' Sustainable Development Goals. Through our analysis of word frequencies and sentiments associated with the core CE principles: Reduce, Reuse, Recycle, we offer insights into the dynamic nature of public discussions and the shifting priorities within the sustainability dialogue. Our study highlights the importance of social media platforms, particularly Twitter, as critical conduits for the dissemination of knowledge, facilitation of community engagement, and shaping of public opinion on key environmental issues.

The observed incremental positive sentiment towards CE within the Twitter sphere suggests an encouraging transition towards a more sustainable and environmentally conscious perspective among its users. This transition is crucial for the broader adoption of CE principles, which aim to minimize waste and resource consumption while promoting a regenerative economic model. Our findings underscore the potential of social media analytics in understanding public perceptions and informing policymaking, educational initiatives, and corporate strategies towards sustainability.

However, we recognize the limitations inherent in our study, such as the focus on English-language tweets and the exclusive reliance on Twitter as a data source, which may not capture fully the global discourse on the CE. Future research could extend this analysis to include a wider linguistic and platform diversity, employ more sophisticated sentiment

analysis methodologies, and explore the relationship between online discourse and tangible sustainability actions.

In summary, our research adds to the expanding body of work on the Circular Economy (CE) and public engagement with sustainability issues. It offers valuable insights that can help policymakers, educators, and businesses align their efforts with public opinions and effectively promote the sustainability agenda based on scientific evidence.

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