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RESEARCH ARTICLE

Integrating climate change practices in a circular economy context—The perspective from chemical enterprises

Walter Leal Filho[1,2] | Kamila Frizzo[3] | João Henrique Paulino Pires Eustachio[2] | Stella Tsani[4] | Pınar Gökçin Özuyar[5]

[1]School of Science and the Environment, Hamburg University of Applied Sciences and Manchester Metropolitan University, Manchester Metropolitan University, Manchester, UK

[2]European School of Sustainability Science and Research (ESSSR), Hamburg University of Applied Sciences, Hamburg, Germany

[3]Postgraduate Programme in Administration, Federal University of Santa Maria, Santa Maria, Brazil

[4]Department of Economics, National and Kapodistrian University of Athens, Athens, Greece

[5]Faculty of Economics, Administrative and Social Sciences, Bahçeşehir University, Istanbul, Turkey

Correspondence

Kamila Frizzo, Postgraduate Programme in Administration, Federal University of Santa Maria, Avenida Roraima, Santa Maria 1000 74C, RS, Brazil.

Email: kamila.frizzo@gmail.com

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Abstract

This study describes the relationships between climate change and the concept of a circular economy, outlining the need for synergies within a company's context. It reports on a bibliometric analysis of the relations between climate change and circular economy, and it provides evidence and assessments based on a sample of 11 large companies in the chemical industry. The results show that there is a concern in the academic literature to discuss circular economy efforts to combat climate change, reduce carbon emissions, strengthen the supply chain, assess the life cycle of products, their environmental impact, and waste management, and identify barriers to implementing the circular economy. In addition, there is a close association between the CE concept and tackling climate change in how organisations report their practices to the stakeholders, in considering concepts of recycling, reusing, adopting renewable energy, seeking resource efficiency, and rethinking strategies. The study concludes by providing some suggestions that may assist companies in intensifying their efforts to reduce their carbon footprint, combining them with more circular business models. Efforts from interested stakeholders must focus on defining CE in a more detailed manner, as well as its implementation at the different stages of production and consumption, especially in operations for which no uniform approach or common practice can be established. In this context, implications for positive social and environmental impacts by promoting a faster and more proactive climate transition in the chemical sector are presented. The novelty of this paper relies on the fact that it advances knowledge on matters related to the circular economy under a climate change context, identifying current trends and suggesting some measures which may optimise current business practices of the chemical sector.

KEYWORDS

chemical industry, circular economy, climate change, enterprises, resources use

1 | INTRODUCTION: THE CIRCULAR ECONOMY AND CLIMATE CHANGE

The concept of a circular economy (CE) has been gaining popularity due to its ability to achieve sustainability at a local, national, and global level and by its explicit inclusion in the long-term strategic planning of large economies (see, for instance, the EU Green Deal and the targets for circular economy). This has mainly been observed in high-income countries, with comparatively little attention being paid to it in developing countries, although things are changing.

CE focuses on optimising the use of natural resources, eco-design, recycling, reuse, waste prevention, and industrial symbiosis, among other vital areas (Schroeder et al., 2019). It describes a model for production and consumption that significantly differs from existing traditional linear economies where the economic benefits are often prioritised, while social and environmental objectives are not always considered (Sauvé et al., 2016).

In this context, the CE differs from the linear production and consumption patterns as it considers the natural environment a valuable resource, focusing on resource preservation rather than just its exploitation. Moreover, it emphasises the need for reuse and recycling rather than concentrating solely on the extraction of raw materials. In addition, each step of extraction production, manufacturing, and the after-life of products is closely monitored and optimised, improving the ability of future generations to meet their needs and greatly promoting the achievement of sustainable development (Sauvé et al., 2016). Table 1 presents some of the features of the chemical industry and its environmental impacts.

Several strategies and principles underlying the CE interact with or impact climate change. The processes of slowing, closing and narrowing loops in construction projects, for instance, have shown that a significant decrease in greenhouse gas emissions (GHG) might be achieved (Gallego-Schmid et al., 2020). This, coupled with other solutions, may prove useful in supporting efforts to tackle climate change (Gallego-Schmid et al., 2020). The process of slowing resource loops involves increasing the time use of products, so as to retain their value over time. Closure of the resource loops that is, using eco-based solutions to decrease the resource intensity and environmental impacts of products and services (Mendoza et al., 2019) promotes the upcycling of products to create new value for used and/or old products (Bocken et al., 2016).

TABLE 1 Some of the features of the chemical industry and its environmental impacts.

Chemical industry	Environmental impacts
Energy intensive use	Large production of CO_2 and other greenhouse gas emissions
Materials intensive	Wide use of natural resources used
Waste production	Potential water/soil contamination when rules are not followed
Water consumption	Large volumes of water are needed, sometimes competing with other uses
Emissions intensive	Potential contribution to air pollution

Source: The authors.

Eco-innovation in the CE has been highlighted as a tool for climate change mitigation. The transition from linear economies to circular ones requires each stage of production and after-life to be optimised to ensure lower GHG and to have minimal environmental impacts (Durán-Romero et al., 2020). In order for this to be achieved, innovation at each step of production and consumption needs to be implemented. Eco-innovation promotes economic growth, protects natural resources, enables transitions to sustainability, and promotes climate neutrality (Wysokińska, 2016). An example is a change from the use of fossil fuels to renewable energy usage in production, which will reduce emissions from processing, increase economic benefits and ultimately improve the profitability of companies (Durán-Romero et al., 2020). Figure 1 showcases the connections between the circular economy and climate change. It can be seen that phases such as the materials extraction and processing are associated with high and medium levels of greenhouse gas emissions, whereas the re-use of some products has a lighter GHG footprint.

The Circularity Gap Report 2019, created by the "Circle Economy Group" at Davos, highlighted three main functions of the CE and its ability to mitigate climate change. Firstly, it highlights the need to reduce the usage of products and extend their economic life (think for instance ridesharing, which reduces the need for individually driven cars and thus reduces GHG emissions). This is further promoted by the increase in autonomous vehicles, which will increase the usage of

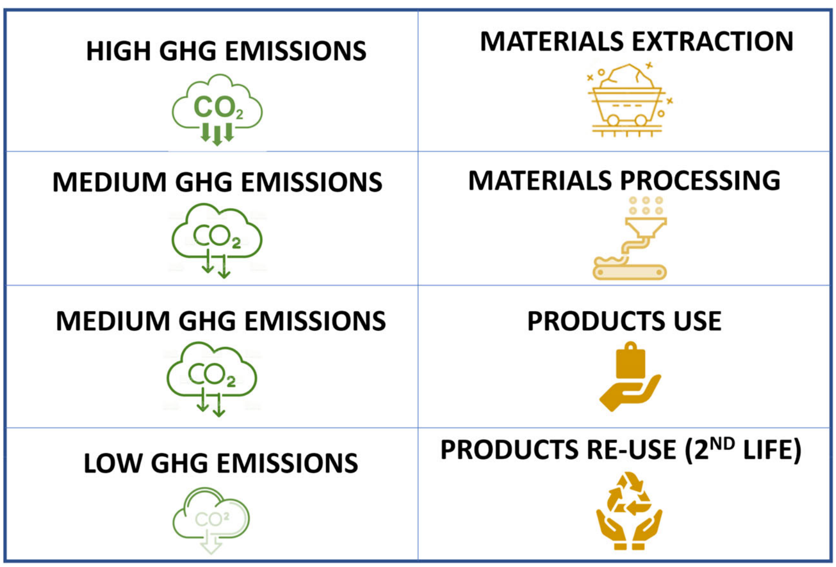


FIGURE 1 Some of the connections between the circular economy and climate change (Source: The authors).

each vehicle by approximately a factor of eight (Circle Economy, 2019). Secondly, CE promotes the usage of waste as a resource as well as the recycling of other products. The design of products needs to be carefully considered in order to ensure that old products may be disassembled with individual components and valuable parts removed. These can either be reused to extend their life cycle or refurbished for usage in other products. The overall benefit is the extension of economic benefits and the reduction of waste, which is very useful since landfill generates large amounts of GHG emissions. Lastly, the circular design reduces material consumption and increases lower carbon-intensive alternatives (e.g. usage of bamboo and wood over cement and metal). Overall, it may be argued that CE consists of a deep transformation of the economic system, demanding new projections and productions of goods by industrial societies (Calzolari et al., 2021) to gain benefits for the environment, society, and companies. Table 2 presents some connections between CE and attempts to handle climate change.

The CE relies on the policies of all those governed, living in a long-term vision, providing incentives, and promoting circular business models that seek resource efficiency and reducing emissions (Khanna et al., 2022). It also depends on companies that develop eco-innovation-oriented business models to achieve resource efficiency, reduce negative environmental impacts, adopt renewable energy sources, and encourage a change in consumer behaviour through CE actions. Lastly, the CE relies on academia to provide CE and climate change courses and develop research for efficiently using raw materials (Khanna et al., 2022).

Wang et al. (2022) also highlighted that CE strategies reduce GHG emissions, maintain the demand for raw materials and new products, support the transition to clean energy, and improve adaptation to climate change. Therefore, CE can be considered a significant catalyst for responding to a global climate crisis (Romero-Perdomo et al., 2022), playing an essential role in reducing GHG emissions, with eco-innovation being a moderator between CE and climate change (Khanna et al., 2022).

TABLE 2 Some connections between circular economy and efforts to handle climate change.

Circular economy	Climate change efforts
Use strategies to re-use and recycling	Avoids the production of new materials whose production is energy intensive
Selection of materials	Use materials which are durable and reduce the need for replacements which may be carbon intensive
Decouple materials production from consumption	Recovery of the energy from materials
Raise interest from consumers	Mobilise consumers for climate action (social perspective)
Foster sustainable business models	Encourages companies to engage in energy efficiency and renewable energy use

Source: The authors.

In this sense, Yang et al. (2023) reported that CE strategies are achieved to combat climate change and can reduce carbon emissions in the industry, waste disposal, energy use, civil construction, and transportation, and improve air and water quality, reduce energy consumption, use of natural resources, and improve the correct disposal of solid and toxic waste. Nevertheless, attention should be paid to the use of bio-based materials in order not to put pressure on land use and land cover.

Whereas the extent to which the CE strategies may contribute to climate change action remains unclear (Cantzler et al., 2020; Durán-Romero et al., 2020), they can play a key role in the context of the Agenda 2030 of the United Nations. In particular, SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all) and SDG 9 (build resilient infrastructure, promote sustainable industrialisation and foster innovation) are quite relevant. Both support the view that sustained growth needs to include industrialisation that makes opportunities accessible to all people, and is supported by innovation and resilient infrastructure.

The development of strategies that lead to circularity and neutrality of carbon has become more necessary in the chemical industry. The chemical industry is essential to modern economies; it consumes a significant amount of raw material and energy and is responsible for significant carbon dioxide (CO_2) emissions (Durán-Romero et al., 2020). The chemical industry uses a substantial quantity of non-renewable energy, including natural gas, petroleum products, and coal, considered the main sources of CO_2 (Xin et al., 2022). Among industrial consumers, the chemical sector consumes the most energy and is the third industrial subsector in terms of direct CO_2 emissions. Direct CO_2 emissions from this industry's primary production totalled 925 Mt in 2021, a 5% increase compared to 2020. Notably, a quarter of this sector's emissions are related to the materials produced, and the rest to fuel combustion (International Energy Agency, 2022). A recent report by the IPCC (2022) revealed that the industrial sector is responsible for 34% of GHG emissions and the chemical subsector for 6.3%. Therefore, the chemical industry clearly stands out as an energy-intensive sector, contributing significantly to global GHG emissions (Alshammari, 2021). Given its position in the national and global value chains, the chemical industry may guide and stimulate a change towards CE models (Accenture, 2019).

Despite the importance of the connections between climate change and the circular economy, there is still a research gap in some key areas. For instance, primary research is needed to better understand the linkages between GHG emissions and specific sectors (e.g. manufacturing, transport). In addition, research on the implications for policy is needed, along with the assessment of the impacts of various business models.

Further, research is also needed to explore the enabling frameworks, technologies and tools, and the barriers to integration. Economic assessments are also needed to explore how the circular economy can contribute to climate action and vice versa. Additionally, analyses of existing circular economy initiatives around the world can provide valuable information to inform future strategies. Moreover, empirical evidence is needed to understand the end users' perception and behaviour and practical implications of the circular economy. Finally, a further gaps is seen in respect of exploring the literature and connections between CE and climate change and to reveal the CE practices that have been adopted by global companies in the chemical sector to combat climate change.

In order to address this last item, this paper focuses on an analysis of the relations between CE and climate change. It does so by describing the associations between climate change and the concept of CE in the chemical industry context through a bibliometric co-occurrence analysis and through the assessment of large companies belonging to the chemical industry that potentially implement innovation activities focused on (environmental, social, and economic) sustainability. This can guide the implementation of circular economy practices (Calzolari et al., 2021) and strongly contribute to reducing the negative impacts of climate change and promoting sustainable development. Furthermore, because of the size, high degree of innovation, competitiveness, international presence, and the intensive use of energy by the companies, these subjects can be discussed more thoroughly in the chemical sector.

2 | CLIMATE CHANGE AND CIRCULAR ECONOMY IN AN INDUSTRY CONTEXT

Negative externalities of climate change are threats that have become increasingly real to the environment, society, and organisations. It has been projected that the impacts of climate change limit economic growth by making poverty decrease more damaging and by challenging food safety (IPCC, 2014). In addition, the pandemic context reinforced the need of rethinking the current economic model—based on "extract-produce-use-spill" flows of materials and energy—and trace sustainable paths for the planet (Ibn-Mohammed et al., 2021).

Under these circumstances, and as a response to climate change, an innovative and more sustainable economic model is required—one that is efficient in the use of resources, that redesigns or creates business models focused on a change of consumption patterns, develops resilience to climate changes and improves the society's quality of life (Durán-Romero et al., 2020). Hence, CE arises as a new paradigm of sustainability (Maldonado-Guzmán et al., 2021), contributing to global climate and sustainable development goals. Even though the literature highlights that CE concepts usually present a weak link with sustainable development (Kirchherr et al., 2017), CE has been acquiring an increasing importance in regard to corporate sustainability strategies, which inevitably include the climate change topic (Calzolari et al., 2021; Derkacz et al., 2021). In this sense, CE can be considered an industrial economy model that aims to dissociate the economic growth of resource consumption, residual management, and wealth generation (Ibn-Mohammed et al., 2021) by promoting the transition to a low-carbon and low-material resilient economy.

Therefore, by keeping materials and products in circulation, CE aims to avoid the extraction and production of raw materials, as well as the processing and manufacturing stages, therefore enabling the decrease of GHG emissions (Deloitte, 2016) and minimising or extinguishing the negative impacts caused by climate change. For Kirchherr et al. (2017), this economy proposal is supported by business models that substitute the idea of a product's life end by reducing or reusing, recycling, and recovering materials in the production/distribution, and consumption processes at the micro, meso, and macro levels. Therefore, ultimately, the CE's purpose consists of reaching sustainable development in the environmental, social, and economic spheres to benefit current and future generations.

To effectively implement circular and low-carbon economies, the companies, government, and society must work together. Companies, therefore, count on mitigation and adaptation strategies to combat the causes of climate change and soften its effects. García-Sánchez and Prado-Lorenzo (2012) have tried to assess the links between greenhouse gas emission practices and financial performance. While mitigation is related to the motors of climate change, adaptation is directed at reducing vulnerability and increasing the capacity to fight against these changes (Sharifi, 2020).

Weinhofer and Hoffmann (2010), in their study on climate change mitigation, added individual measures for managing emissions into sets of measures that meet the same strategic objective. For the authors, the sets are the types of CO_2 strategies that emphasise different strategic decision time points: CO_2 offset, CO_2 reduction, and carbon independence. Cadez and Czerny (2016) suggest three main corporate climate change mitigation strategies to reduce CO_2 emissions: internal carbon reduction, external carbon reduction, and carbon compensation.

Climate change will have significant impacts on firm infrastructure, production processes, and supply chains, in particular, because of the physical impacts on operations, resource access, and distribution (Linnenluecke et al., 2013). According to the authors, traditional business adaptation responses occur through measures such as implementing cost savings or superior production processes, lobbying to change regulatory conditions, and actively managing their reputation, for instance, through increasingly reporting on their social and environmental performance. Thus according to the United Nations Framework Convention on Climate Change—UNFCCC (2019), the adaptation strategy is related to changes in processes, practices, and structures to moderate potential damages or benefit from opportunities associated with climate change to contribute to business continuity and respond to market and environmental changes.

Companies can contribute to climate change adaptation by instituting new practices within their operations to manage climate risks and impacts (physical, price, regulation, reputation, and liability), developing products and services and engaging with governments, communities, and other stakeholders to put policies and ground-level practices in place that contribute to long-term resilience (UN Global Compact and UN Environment Programme, 2012; UNFCCC, 2019). Thus, some actions aimed at adaptation can be considered by-products of mitigation activities (Tompkins et al., 2010).

In this way, CE can contribute to a more resistant, more resilient, and more adaptable society to climate change by dealing with materials, energy, space, water, and food in a smart and sustainable way (OVAM, 2018). In addition, CE can reduce global GHG emissions by 39% and reduce the use of virgin raw materials by 28% through its strategies (Circle Economy, 2021).

Hence, the CE model can be understood as a complement to efforts towards developing low-carbon economies, which are more resilient and sustainable and facilitate the achievement of climate goals in the entrepreneurial context. Then, to reach this radical and systemic change, a new way of thinking and doing business must be created, which combines different models and strategies of business, approaches, methods and design tools (Bocken et al., 2016). In this sense, circular business models define how companies create value and adhere to the CE principles (Lüdeke-Freund et al., 2019).

Companies that have some part in the market and that have the activation capacity in several vertical stages of the linear value chain may perform an important role in CE innovation (EMF, 2015). Thus, large companies have an essential role in the transition of the linear economic paradigm to the circular economy as they define what is produced and consumed, being able to use eco-innovations to make their production methods cleaner, introduce renewable energy sources and change the consumer's behaviour regarding the CE principles (Durán-Romero et al., 2020) Hence, eco-innovation in products, processes and management facilitates the transition to a more CE in productive processes (Maldonado-Guzmán et al., 2021).

Cantzler et al. (2020) observe that the largest GHG economies may be associated with the industry, energy and transportation sectors, and industry may have the highest potential for reducing emissions related to CE. Thus, industries can stimulate the transition from a linear economy to a circular one through several practices, such as the manufacturing of sustainable products of easy repair, adopting technologies to increase the useful life of products, and promoting material recycling remanufacturing (Calzolari et al., 2021). Cantzler et al. (2020) have analysed reports from large companies to show how the adoption of CE practices has taken place in industrial organisations and in their global supply chains, and they have identified the following activities: cross-cutting, efficiency, rethink, renewables, reduce, reuse and waste valorisation/recycle. In their study, Calzolari et al. (2021) have observed the following CE strategies: recycle, renewable energy & resource efficiency, reuse, reduce and recover.

However, not all circular practices positively impact the environment, minimising risks and effects of climate change. In addition, the resilience level to the climate risks that CE may provide depends on the context, because climate risks and vulnerability vary based on the industry, geography, and socioeconomic reality (EMF, 2019) Hence, according to the IPCC (2014), we need to consider different options to combat climate change in each of the main emitting industrial sectors (iron and steel, cement, chemicals, paper and cellulose, aluminium, food processing, textile and leather, and mining), as well as the fact that countries present different climate risks related to the economic development, import/export dependency of materials and goods and the political scenario (EMF, 2019).

The chemical sector plays a significant role in shaping biodiversity, both positively and negatively. For instance, chemical industries can release pollutants into the environment through various processes, such as manufacturing, waste disposal, and emissions. These pollutants, including toxic substances and heavy metals, can contaminate the air, water bodies, and soil, leading to habitat destruction and adversely affecting biodiversity. For example, oil spills have devastating effects on marine ecosystems, causing harm to fish, birds, and other organisms. In addition, the chemical sector produces pesticides and herbicides used in agriculture to control pests and weeds. While these chemicals can enhance crop production, they can also have unintended consequences for biodiversity. Pesticides can harm beneficial insects, such as bees and butterflies, which are essential for pollination. Additionally, they may enter the food chain, impacting other organisms and disrupting ecological balance. A further element is that the expansion of chemical industries often involves clearing natural habitats, leading to habitat fragmentation. Large-scale infrastructure projects, such as factories, refineries, and pipelines, can disrupt ecosystems and fragment habitats, limiting the movement and dispersal of species. This fragmentation can result in isolation, reduced genetic diversity, and increased vulnerability to extinction for many species. There is therefore a perceived need to exercise great care with the operations of the chemical sector, so that it does not endanger biodiversity.

In this context, one can observe that caring for biodiversity is a great obstacle for all companies (Venturelli et al., 2023), even more so for the chemical sector; nonetheless, in the CE context, biodiversity protection is seldom mentioned (Buchmann-Duck & Beazley, 2020). According to the authors, the CE can contribute both positively or negatively to biodiversity as CE defends biomimetic, valuation of ecosystem services, bioeconomy, and renewable energy that may present conflicts with biodiversity protection if it is not well planned. Given this scenario, the CE must address aspects related to biodiversity protection so as not to have side effects and negatively impact it (Buchmann-Duck & Beazley, 2020). For this, Ali et al. (2018) proposed a model to help CE decouple economic growth from negative biodiversity-related impacts by addressing need and scope definition, stakeholder identification, regulation and finance, environmental impact and comparison of offsets, and offsetting and credit generation.

It is also known that industrial production processes mainly use fossil oils and conventional resources that are exhaustible/finite (Arbolino et al., 2020), which contributes to climate change and negatively impacts sustainable development. According to the International Energy Agency (2022), the chemical sector is the largest industrial consumer of oil, gas, and energy and represents the third subsector of the industry in terms of direct emissions of CO_2, which happens because half of the energy emissions is characterised as raw material that is then released for use in other sectors (automotive, clothing, electronics, food, toys, construction, and packaging). However, the chemical sector is essential to daily life, because society is constantly exposed to chemical products (food, air, and clothes, for instance) (European Commission, 2020b).

In this scenario, the EMF global commitment to the new plastics economy represents a complex challenge to the chemical industry, because it requires that all the plastic packaging used by the involved companies is reusable, recyclable, or compostable by 2025 (Accenture, 2019; EMF, 2021). Besides, regulations and the interests of shareholders and consumers have also demanded a more proactive posture of the industry towards CE. Thus the chemical industry has opportunities that allow it to anticipate new trends, develop business strategies, and offer innovative solutions (Accenture, 2019), given that, according to the International Council of Chemical Associations (ICCA), innovation in the sector may increase energy efficiency and reduce GHG emissions.

This sector may then implement circular solutions in its internal processes and stimulate circular systems in the value chains (ICCA, 2020), considering that chemical products affect the circular potential of other products (such as resins and varnish that do not enable the reuse of wood furniture) (Accenture, 2019) Thus, the adoption of CE practices in business models of the chemical sector is an important element in the equation of climate change, when introducing the circular innovation concept in the management of mitigation and adaptation processes.

3 | MATERIALS AND METHODS

Two methods were used to address this paper's goals. Firstly, a bibliometric analysis was carried out to unveil the main research streams in climate change and CE. Secondly, the authors assessed the annual and sustainability reports and websites of the 11 companies from the chemical industry listed in the Global Fortune 500 ranking (2021), which is based on circularity strategies for tackling to climate change. The choice of the 11 companies is also based on the fact that they have a proven engagement on matters related to circularity and climate change, such as eliminating waste, lower material and resource consumption, and efforts towards reduction of greenhouse gas emissions.

The methods used are complementary to each other in identifying the thematic focus of the CE area and climate changes in the entrepreneurial scope, as well as the current trends of entrepreneurial practices in the chemical industry.

For the bibliometric analysis, the documents were collected from the Scopus Database, a well-known database of peer-reviewed literature that includes over 24,000 publications and more than 5000 journals (Scopus, 2021). In order to identify papers related to CE and climate change, a search string was developed in three thematic blocks. The first part considered terms associated with climate change, such as carbon emissions, carbon footprint, and Paris Agreement. The second, in turn, used terms related to companies (enterprises, supply-chain management and industry), given that the object of study was focused on companies from the chemical industry. The last group of terms was connected to the CE and related strategies. Variations of the adopted terms were also tested to achieve the final configuration of the search string, resulting in 1906 documents. Table 3 shows the search criteria used to identify the sample of peer-reviewed documents.

TABLE 3 Search criteria and number of documents in the Scopus database.

Search string	Number of documents	Database
TITLE-ABS-KEY ((“climate change” OR “climate impact” OR “carbon emission*” OR “carbon footprint” OR “greenhouse gas” OR “greenhouse gases” OR “Paris Agreement” OR “climate “) AND (“company” OR “companies” OR “enterprise*” OR “firm*” OR “business” OR “supply chain*” or “industry”) AND (“circular economy” OR “circular economies” OR “circularity” OR “cradle-to-cradle” OR “closed loop”))	1096	Scopus

The VOSviewer software (version 1.6.16) was chosen to perform the data analysis (VOSviewer, 2021). The software used is a text mining software commonly used to reduce the complexity of a research field, in which it is possible to build and visualise literature network graphs. The technique deployed for this study was the co-occurrence analysis of terms, in which the output can be visualised through a network map where the diameter size of the circles represents the co-occurrence frequency of a term, whereas the width of links shows the strength of connections between two terms. Finally, when the terms co-occur, they are expected to be close to each other and are likely to become a cluster represented by different colours in the figures (Perianes-Rodriguez et al., 2016; van Eck & Waltman, 2010, 2014).

We collected data to assess the tackling of climate change and strategies of the CE through case studies in a sample of 11 companies from the chemical industry based on the Global Fortune ranking (2021)—–BASF, ChemChina, Zhejiang Rongsheng Holding Group, Zhejiang Hengyi Group, Dow, Shenghong Holding Group, 3 M, Mitsubishi Chemical Holdings, LyondellBasell Industries, Linde, and LG Chem. It was done following secondary qualitative data found in annual and sustainability reports and corporate websites. These evidence sources were analysed to assess how global companies in the chemical industry deal with climate changes under the CE perspective. It is noteworthy that company reports aim to communicate their sustainable practices that contribute to sustainable development. Communication on sustainability is a voluntary action that is increasing in the corporate context (Thijssens et al., 2016), as sustainability reports show how companies have been dealing with sustainability challenges and can enable gains/benefits to the companies (Higgins & Coffey, 2016). Most of the collected information was in English.

Data provided by the companies were analysed based on their content. We collected relevant data with the support of Microsoft Excel, according to the CE theme and its classifications. CE practices were ranked according to the following strategies: recycle, reuse, rethink, renewable energy & resource efficiency, reduce, and recover.

The categories placed in Table 4 holistically represent some of the key areas where the action is needed by companies if they are truly committed to addressing climate change. This includes the

TABLE 4 Circular economy (CE) strategies adopted.

CE strategies	Description
Recycle	End-of-life products, parts, components, and materials are reprocessed to make new products, parts, components, and materials. Includes also remanufacturing and recycling.
Reuse	Products' life is extended through repairing, preventive maintenance, and refurbishing actions; products and components are reutilised for their original function.
Rethink	Concepts are rethought.
Renewable energy and resource efficiency	Incremental efficiency improvement of production or logistics processes, or adoption of renewables as a source of energy. Linear flows of materials are not challenged.
Reduce	Products are innovated to make a more intensive use of resources.
Recover	Energy is recovered from by-products or waste, either directly or through the production of alternative fuels like biofuels.

Note: Based on Cantzler et al. (2020) and Calzolari et al. (2021).

commitment to reduce the need for resources and foster their use—in line with the principles of CE—but also deploying renewable energy to curb their CO_2 emissions. The size of chemical companies means that their contribution is potentially quite significant. In a second step, the content was reviewed to categorise the CE practices, integrating the specific practices of each company analysed in general categories to facilitate the analysis of corporate practices from the chemical industry.

4 | RESULTS AND DISCUSSION

Next, the results and discussion of the bibliometric analysis and reports of chemical companies are presented, based on the two central themes of this study: circular economy and climate change. It should be stated that the bibliometric describes the presence of the topics in the literature as a whole. The thematic analysis zooms in on the specific issues associated with the industry, which were integrated into respect of providing a solid background on the topic. Both elements provide a basis upon which the findings are discussed and crosschecked here in section 4.

4.1 | Bibliographic analysis

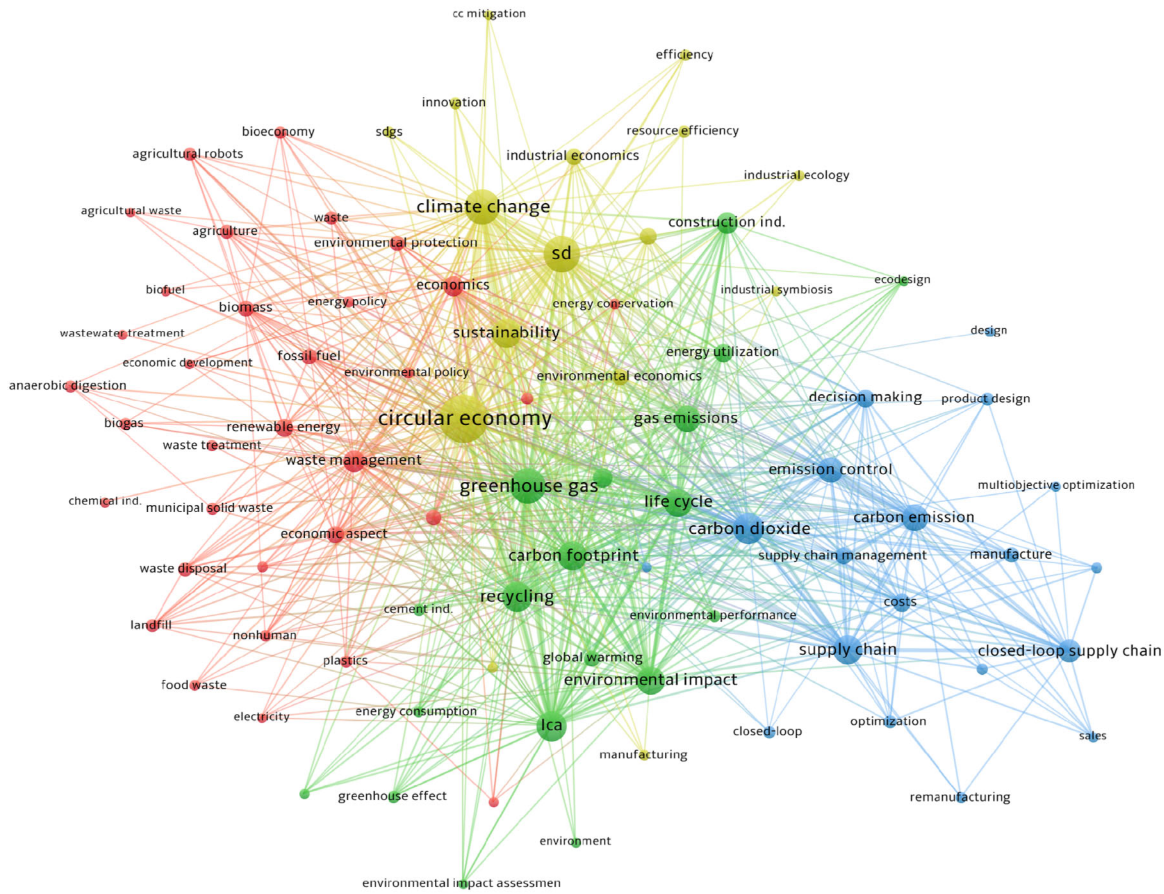
Figure 2 indicates that a circular economy has been routinely discussed in relation to waste management, carbon emissions, climate change, and supply chains. Scopus search returned 1906 documents, and four main clusters were identified among the main search strings discussed by researchers on circular economy and climate change.

The yellow cluster is related directly to the circular economy and embraces terms connected to sustainability, sustainable development, and climate change. The main discussion in this cluster is related to the importance of circular economy and climate change mitigation policies (Durán-Romero et al., 2020; Gallego-Schmid et al., 2020), as well as the role of universities, firms, governments, and other important actors belonging to the natural and social systems that play a crucial role in contributing to the circular economy through eco-innovations (Durán-Romero et al., 2020). This cluster is also related to the broad discussion on how circular economy strategies could contribute to achieving the SDGs. Schroeder et al. (2019) suggested that the most evident contribution from CE practices towards the SDGs are related to clean water and sanitation, affordable and clean energy, decent work and economic growth, responsible consumption and production, and life on land. Other studies also go in the same direction, identifying statistical relationships between circular economy practices and SDGs compliance through exploratory factor analysis (Rodriguez-Anton et al., 2019). Finally, the yellow cluster also suggests the importance of industrial policies and economic factors involved in the adoption of CE, since there is evidence that the cost of reprocessing some materials, such as aluminium and plastic, is not only cheaper but also requires less energy than creating products from new materials (Geng et al., 2019).

The blue cluster refers to the discussion of carbon emissions and supply chains, with related terms such as closed-loop supply chain, carbon dioxide, and supply chain management. This cluster shows the main discussion about how companies could optimise the supply chain by implementing practices and strategies related to the CE to reduce carbon emissions and create self-sustaining production systems (Genovese et al., 2017). Examples of studies belonging to this cluster rely on the proposal of circular business models that could foster sustainable development (Geissdoerfer et al., 2018), decision-making models that identify the social costs of carbon emissions (Tseng & Hung, 2014), carbon capture and storage policies (d'Amore et al., 2021; Leonzio et al., 2019), and models for closed-loop supply chains and maximisation of environmental benefits (Liao & Li, 2021).

The green cluster is related to the connections between the CE, life cycle assessment, greenhouse gas emissions, and carbon footprint. Studies in this cluster focus on exploring evaluation techniques or measuring the environmental impact of a product or a process, guaranteeing more sustainable consumption and production patterns (Peña et al., 2021). For example, Liu et al. (2021) conducted a literature review about the environmental impact of biorefineries, developing a comprehensive framework for future research, and Malabi Eberhardt et al. (2021) studied the environmental impact of the building industry, suggesting the best designs and strategies could lead the sector towards a CE and helping to combat global warming.

The red cluster develops in a two-fold manner. From one side, it refers to the importance of waste management and the paths to implement/enhance it for a circular economy (Pires & Martinho, 2019). It also entails the identification of the critical factors



Note: Co-occurrence of the terms – *VOSviewer* output

FIGURE 2 Co-occurrence of the terms circular economy and climate change. co-occurrence of the terms—*VOSviewer* output.

(Salmenperä et al., 2021) as well as the main barriers during the efforts to this transition, such as the lack of regulatory pressures, innovation capacity, cost, and financial challenges, lack of environmental education and stakeholder cooperation (Zhang et al., 2019). On the other hand, the red cluster discusses the CE and energy-related aspects, such as the relevance of renewable energy (Olabi, 2019), energy conservation and consumption (Li et al., 2010), the transition from fossil fuels (Mutezo & Mulopo, 2021), waste-to-energy and biofuel adoption (Sharma et al., 2020) and the growing concerns for implementing CE strategies.

4.2 | Analysis of large companies in the chemical industry sector

4.2.1 | Characteristics of the companies investigated

Table 5 summarises the main characteristics of the companies investigated as to their location, type, revenue, number of employees, year of foundation, type of climate and circular innovation, engagement with stakeholders to promote climate and circular action, participation as a signatory in sustainability initiatives, and dissemination of sustainability and GRI reports.

The characteristics show that most of the analysed companies have broad market experience, having been through different changes and demands of the market and society. The companies analysed have their headquarters in seven countries: (1) Britain, (1) Germany, (1) Japan, (1) the Netherlands, (1) South Korea, (2) the US, and (4) China. This exemplifies the global context of practices linked to the circular economy and climate change, as well as the availability and content of the annual and sustainability reports and other dissemination media made available by the sector. This global perspective has relevance, since according to Cadez and Czerny (2016), the corporate strategies related to climate change may rely on carbon dependence, the industrial sector, and the geographical location of companies.

The companies investigated are of different types. Most of the companies are classified as open companies in terms of the stock market and, for this reason, they generate actions for the public, are large-sized businesses, have substantial revenue, and have a large number of employees. Regarding the innovation aspects, the companies assessed seek to innovate in products, processes, and

TABLE 5 Companies analysed.

Company	Year	Country	Type	Revenue ($M)	Employees	Innovation	Collaboration	Signatory	Annual sustainability report	GRI report
BASF	1865	Germany	Public	$69464.3	110,302	Product, process, and organisational (business model)	Customers, universities, research institutes, companies, and local authorities	Global Compact	Yes	Yes
ChemChina	1984	China	Private	$60491.9	141,250	Products	Research institutions	Not found	Yes	Not found
Zhejiang Rongsheng Holding Group	1989	China	Private	$44725.9	20,493	Processes and products	Research institutions	Not found	Not found	Not found
Zhejiang Hengyi Group	1994	China	Private	$38561.7	22,019	Products and processes	Colleges and universities	Not found	Not found	Not found
Dow	1897	U.S.	Public	$38,542	35,700	Projects, products, and processes	Various parties	Global Compact Science Based Target	Yes	Yes
Shenghong Holding Group	1992	China	Private	$38,440	32,272	Processes	Universities	Not found	Not found	Not found
3 M	1902	U.S.	Public	$32,184	94,987	Product, process	Customers, suppliers, research centres, and local authorities	Global Compact	Yes	Not found
Mitsubishi Chemical Holdings	2005	Japan.	Public	$30729.1	69,607	Product, process, organisational	Customers, universities, research institutes, companies, and local authorities	Global Compact	Yes	Yes
LyondellBasell Industries	2005	Netherlands	Public	$27,753	19,200	Product, process, organisational	Research institutes, companies, and local authorities	Global Compact	Yes	Yes
Linde	1879	Britain	Public	$27,250	74,207	Product, process	Local communities	Science based target	Yes	Yes
LG Chem	1947	South Korea	Public	$26644.8	40,234	Product, process, organisational	Research institutes and governments	Global compact	Yes	Not found

organisational processes and policies. Moreover, the companies are part of a highly innovative sector that is also one of the major pollutant-emitting sectors, and this requires guidance directed towards sustainable innovation. Thus, companies collaborate with customers, suppliers, universities, research institutes, other businesses, local communities, and local authorities to promote climate and circular actions.

Among the companies, seven have joined initiatives, such as the Global Compact and the Science-Based Target. It is also noteworthy that most companies (8) disclose their sustainability reports as a way to present their innovative and sustainable practices and business investments publicly, discussing CE and climate change as interconnected themes. The majority (6) do not have a report following the GRI guidelines. In addition, three companies do not discuss the circular economy and climate change in their communications as being interconnected. This can be justified because the circular economy is somewhat a new topic for companies that belong to the chemical industry.

4.2.2 | Circular economy strategies in the chemical sector

Regarding the recycle and reuse strategy, different practices were identified: recycling and reduction of materials, components, or waste; research for material recycling; investments in efficient recycling processes; investments in solutions that minimise and manage plastic waste and promote post-use solutions; programmes to increase the use of recycled raw materials; reuse of wastewater; close the loop target for materials; green refining chemical plant; reforestation.

In this context, it was possible to verify that BASF processes recycled and waste-based raw materials, replacing fossil-based raw materials. Therefore, it works with partners in chemical recycling projects, transforming plastic waste into secondary raw material and saving fossil resources. In this process, plastic waste is not incinerated but used to create new chemicals, which release less GHG into the environment. It is engaged in: the chemical recycling of tires; research and development of mattress recycling, reducing the waste of valuable raw materials and generating a significantly lower carbon footprint; development of innovative and sustainable steps for battery recycling, contributing to sustainability in the battery value chain for the automotive industry, by closing the loop and reducing the CO_2 footprint; investment in sustainable and efficient technological recycling processes, meeting the unmet needs of the sector; circular economy programme to increase the use of recycled raw materials; cooling water recirculation; reuse of wastewater from the production process whenever possible; and investment in solutions that minimise and manage plastic waste and promote post-use solutions (recycling, reuse, and repurposing), as a founding member of the global Alliance to End Plastic Waste. The company seeks to fight deforestation through its operations, products, and raw material supply chain.

Zhejiang Rongsheng Holding Group has a green refining chemical plant; produces recycled environmentally friendly paper, and has new energy comprehensive utilisation projects. Zhejiang Hengyi Group repairs and recycles wooden pellets in its operations, and crosscuts climate change through reforestation.

Dow, in turn, seeks to stop waste through reuse or recycling, and minimise waste through its direct actions and partnerships. With that in mind, the company is investing in and collaborating with key technologies and infrastructure, closes the loop for materials by making all of its products sold in packaging reusable or recyclable, and recycles plastics from post-consumer recycled products in its plastics circularity portfolio. 3 M reuses products (e.g., face masks), develops recyclable packaging, and uses circular materials. Mitsubishi Chemical Holdings performs recycling and waste reduction. LyondellBasell Industries develops mechanical and advanced (molecular) recycling solutions to meet customers' and brand owners' circularity goals. In its portfolio, it has polymers made using renewable raw materials, such as vegetable oil and oil waste, as well as advanced (molecular) and mechanically recycled materials. It develops products made from used post-consumer or post-industrial plastics and products made from renewable feedstock, such as used cooking oil, which reduces the amount of CO_2 used, helping to tackle climate change. Linde has a zero-waste policy. Finally, it was possible to verify that LG Chem uses post-consumer recycled plastics, has zero landfill on all its sites, and performs mechanical recycling for recycled plastics.

It is noteworthy that CE drives the reuse of water and, as the scarcity of this resource can have harmful effects on the environment and the economy, in addition to water efficiency measures, the reuse of treated wastewater is a resource to increase water supply and alleviate the pressure on water resources (European Commission, 2015), an action for adapting to climate change. In this sense, water is an important issue to be considered, as it is a scarce resource that requires sustainable treatment of effluents and improved water efficiency and which contributes to reduced energy consumption (Durán-Romero et al., 2020).

Another highlight is that companies in the chemical sector are concerned with recycling plastics, seeking to use fewer virgin materials to reduce waste generation. According to McKinsey Sustainability (2020), 60% of plastics could be originated from recycled materials by 2050. Hence, the European Commission (2020a) supports a global agreement on plastics and promotes the uptake of a CE approach aimed towards plastics in the European Union.

Furthermore, according to the United Nations (2019), forests are important for climate regulation, water resources management, and biodiversity conservation. Reforestation can be linked to CO_2 recycling that is, the circular carbon economy contributes to the absorption of CO_2, removing it from the atmosphere and reducing global warming (Alsarhan et al., 2021). Reforestation can be considered a form of compensation for sectors that have limitations in mitigating climate change (McKinsey Sustainability, 2020). Thus, such practice can contribute resilience to a society in transition to a low-carbon economy.

Regarding a rethink, there has been a shift towards natural and/or renewable raw materials, the development of sustainable products, services, and technologies, the creation of circular business models, solutions to increase the durability of products, and SHE management system (reports), zero sulphide emissions, emission control, value creation through digital transformation and design circularity.

BASF develops products with natural and renewable raw materials and from by-products. For example, biopolymers can help reduce food waste, returning nutrients to the soil through the greater volumes of compost generated and preventing the accumulation of plastics in the soil. Thus, the company seeks to use products in the best possible way throughout the value chain, keep them in use as long as possible, and recover them at the end of their useful life, generating less waste and pollutants. The company conducts research on how fossil and petrochemical resources can be replaced by non-fossil alternatives, considering economic, environmental, and social aspects, as well as sourcing safety and product safety. The aim is to increase the share of renewable and recycled raw materials in value chains. Thus, the company also seeks to develop green products and technologies for customers. The company also has circular business models.

ChemChina develops sustainable products and services, especially for the farmers' customer base. It implemented a SHE (safety, health, and environment) management system in the parent company and subsidiaries, created new energy recovery and sulphurisation facilities that reduced total sulphur emissions, and developed new environmentally friendly products, such as eco-friendly tires. Zhejiang Hengyi Group invests in the development of new green, bio-based and circular economy products, seeking to achieve carbon neutrality. Dow addresses circularity in its designs. Shenghong Holding Group carries out air and wastewater treatment in its printing and dyeing industry, contributing to green ecological development, and performs emission control. LyondellBasell Industries creates value through digital transformation, engages with high-value initiatives through digital applications, accelerates the development and deployment of digital technology, and promotes "digital natives". LG Chem develops bioplastics and biodegradable plastics.

The use of bio-based products and materials by companies contributes to a transition to a bio-economy and to circularity in the chemical sector. The bioeconomic transition includes reducing the use of fossil resources through biological resources that use innovative and clean technologies and providing solutions to economic, social, and ecological challenges, such as resource depletion, food insecurity, and climate change (Jander & Grundmann, 2019; Wydra et al., 2021). Thus, biochemicals can substitute conventional chemicals, hence contributing to energy security and climate change mitigation (Nong et al., 2020). A circular economy is an economy where bioresources are used to make products with the highest possible added value in a sustainable way, on a cascaded use of materials, minimising resource input (from) and output (to) the natural environment (Salvador et al., 2021). However, new business models are needed that integrate the entire value chain, contributing to mitigation, resilience, and adaptation to climate change.

The renewable energy and resource efficiency strategy used includes:

1. digital tools and data to improve resource efficiency and avoid resource consumption;
2. increased use of renewable energy;
3. more effective production systems;
4. research and development of new processes and technologies to reduce GHG;
5. development of climate protection products for emission reduction and resource efficiency;
6. promote the efficiency of internal resources;
7. support to improve production systems and supply chain resource efficiency, including by-products as raw materials;
8. use of steam and electricity generation technologies;
9. fuel/emissions/sewage management system for energy conservation and emissions reduction

In addition, carbon asset management as a tool is being deployed.

BASF has digital tools and data to improve resource efficiency and avoid resource consumption (e.g., solutions for agriculture) and has efficient technologies for steam and electricity generation. It increasingly uses renewable energies, develops efficient production processes through comprehensive energy management, conducts research and development of new processes and technologies to reduce greenhouse gas emissions, and develops climate protection products that contribute to emission reductions and resource efficiency. It seeks to introduce sustainable management of water at production sites, and in areas of water stress and on its sites, it seeks to use this resource responsibly throughout the entire value chain and especially in water catchment areas at production sites, along with its aims to protect water, continually improve water use efficiency, and consistently reduce emissions. It reduces the resources consumed in the production of products by implementing more efficient processes contributing to sustainability, such as a lower carbon footprint. Its products also seek to improve resource efficiency and customer sustainability by requiring less material and generating water savings and energy cost savings. By-products from one facility are used as raw material elsewhere, saving raw material and energy and contributing to the creation of efficient value chains.

ChemChina has measures in place to phase out high fuel consumption and high emission devices and is exploring technologies to complete "zero emissions" sewage projects and protect water resources. It has a management system for energy conservation and emissions reduction, and it pursues material efficiency. It performs carbon asset management, develops green design products and green manufacturing technology with the energy efficiency of tire products, promotes a project for comprehensive water treatment, recycles resources and implements "zero emissions" of wastewater in the company, and uses solar energy.

Zhejiang Rongsheng Holding Group has a clean production by strengthening wastewater and waste gas treatment facilities, with technical changes for energy savings and emission reduction. Zhejiang Hengyi Group has a smart and green manufacturing model in its production process, which saves energy, reduces consumption, and performs the waste treatment. Dow seeks to reduce carbon emissions to neutrality, and it implements and advances technologies to manufacture products using fewer resources and to help customers reduce their carbon footprint. 3 M seeks to innovate to decarbonise the industry, accelerate global climate solutions, and improve the environmental footprint. It develops roofing materials that improve air quality and address climate concerns, such as reducing smog. It covers granules, uses automotive electrification, implements multilayer films that improve solar panel effectiveness and increase electronics efficiency and develops products for the electric energy industry that do not generate greenhouse gas impacts. Mitsubishi Chemical Holdings has switched from fossil fuels to renewable raw materials (plant-based and based on other natural resources). LyondellBasell Industries implements enhanced energy management and low emission steam, process electrification and furnace upgrades, flare minimisation, the use of lower-emitting fuels, and procurement of electricity from renewable sources. Linde uses hydrogen for transport. LG Chem has a green premium programme.

4.2.3 | Looking at the evidence

From the evidence, it was possible to note that non-fossil-based resources have been used by the sector, contributing to a transition to renewable energies, in addition to a greater use of digital tools and data to increase resource efficiency. The industry 4.0 technologies collect, process, and integrate a large amount of data, optimising production processes that may support CE strategies (di Maria et al., 2022) and contribute to a more sustainable agriculture production (Zscheischler et al., 2022).

As for the reduce strategy, practices related to climate change were identified through GHG emissions monitoring; the generation of net zero; recyclability, energy, water, and rare metals savings; responsible sourcing; renewable materials and/or reuse suitable for the specific product; and reduced carbon footprint in production.

BASF seeks to optimise global energy consumption and save raw materials. ChemChina performs "zero emissions" management. 3 M performs recyclability, energy, and water savings, responsible sourcing, renewable materials, and/or appropriate reuse for the specific product. Mitsubishi Chemical Holdings seeks to reduce the use of raw materials in manufacturing and the use of utilities, reduce the use of rare metals in product production processes, and reduce the group's impact on water resources by solving water supply and demand problems. Linde seeks to reduce the carbon footprint of production, use low-carbon energy, and decarbonise production. LG Chem has a reduced carbon footprint.

Finally, recovery is related to the production of products from residues to the production of energy and fuel, and investments in energy recovery facilities. BASF performs the replacement of fossil raw materials with second-generation renewable raw materials and uses residues as well as waste materials. As a result, it reduces GHG emissions by at least half. For instance, the company produces methanol balanced with biomass, which is considered an energy supplier and can contribute to fuel production. In addition, in collaboration with another company, BASF has been developing sustainable technology for the transport sector to produce bio-based propanol from industrial waste to be used as a component of gasoline. Such technology aims at reducing 65%–75% of the CO_2 footprint when compared to fossil fuels. ChemChina has created new energy recovery facilities.

4.2.4 | The role of eco-innovation

From the evidence shown, the circular economy practices that stand out in this sector seem to be associated with the "recycle and reuse", "renewable energy and resource efficiency", and "rethink" strategies. Such circular economy strategies are associated with the internal carbon reduction strategy concerning process emissions reduction and combustion emissions reduction, as defined by Cadez and Czerny (2016). In this context, external carbon reduction practices were also identified concerning supply chain emissions reduction, as companies seem to be strongly involved with the entire value chain, seeking to reduce their emissions, for example, by encouraging best practices by suppliers and developing circular products so that their customers can offer circular products. Chemical industries may have an important role in the creation of value for other companies by providing new products, services, and models of sustainable businesses (Manda et al., 2016). The company's involvement with the supply chain with regard to sustainability is of great importance because product consumption is expected to increase and companies will be increasingly vulnerable to drought, government limits on GHG emissions, and reputational damage. Therefore, the best opportunities for sustainable performance may lie in the supply chain that is responsible for much of the emissions and environmental impacts caused by consumer companies (McKinsey Sustainability, 2020). Cooperation across the value chain is critical in a circular economy, where knowledge is shared and co-creations are developed (OVAM, 2018). Thus the sector seems to involve the supply chain in its efforts towards a circular, low carbon, and resilient economy. This finding corroborates the study by Cantzler et al. (2020) when they identified that most studies on the industry deal with recycling, reuse, or material substitution (bio-based products).

Evidence demonstrates that CE can be considered a form of mitigation and adaptation to climate change and that many CE strategies are interconnected, as well as the strategies of climate change adaptation and mitigation. Most companies address CE and climate change jointly in their reports but do not show emission indicators based on their CE practices.

Companies develop eco-innovations seeking to mitigate and adapt to climate change through CE, mainly at the level of products and processes. Business models that are focused on product and process innovation that seek to reduce the consumption of fossil materials, replacing them with natural resources, for example, and that seek to increase material and energy efficiency can reduce the negative impact on the environment and society, contributing to the economic outcome. CE evidence in the companies' operations can help fight the generation of materials and GHGs, along with the lack of resources that society experiences and will increasingly experience if smart and sustainable alternatives are not implemented.

5 | CONCLUSIONS

Chemical companies are energy and material-intensive, generating negative impacts on the environment and impacted by climate change (Axon & James, 2018). However, they can rethink their actions by incorporating circular strategies that contribute to climate change mitigation and adaptation so that they can respond positively to the market, society, and the environment (Cucciniello & Cespi, 2018; Keijer et al., 2019).

In this sense, this study sought to explore through a bibliometric analysis the research streams that authors are exploring regarding the circular economy and climate change. In addition, an assessment was made of the sustainability reports of 11 companies belonging to the chemical industry while considering the main constructs related to the circular economy.

From the bibliometric analysis, four main clusters were identified. The first cluster considered peer-reviewed papers that aimed to explore how a circular economy, when adopted by companies, could contribute to combating climate change (Somoza-Tornos et al., 2020). The second indicated the efforts to reduce carbon emissions and supply chain optimisation by implementing sustainability practices and sustainable supply chain management (Centi et al., 2013). The third, in turn, evidenced the broad discussion on life cycle assessment and environmental impact measurement techniques (Abdelrahman, 2022), while the last cluster focused on practical aspects of waste management and the critical aspects and the barriers to implementing CE (Loste et al., 2020).

From the analysis of the sustainability reports, the results indicate some common approaches as well as common intervention areas that can strengthen the application of sectoral CE practices. In this sense, a general finding shows the close association of the CE concept and tackling climate change in how they report their practices to the stakeholders, considering concepts of recycling, reusing, adopting renewable energy, seeking resource efficiency, and rethinking strategies (Stewart & Niero, 2018). These include research and development for recycling and reuse of materials, components, or waste (e.g., plastics, tires, mattresses, batteries, papers, face masks, wastewater); digital tools and data; the increased use of renewable energy; improved production systems and supply chain resource efficiency; a shift to natural raw materials (biomaterials) and innovation to circular business models. These commonalities may serve as defining factors for the practical implementation of CE by companies in the chemical sector. At the same time, they indicate the less common approaches recorded across companies that highlight the segments of operations where CE application is less well understood and where more can be done by clarifying its implementation. Efforts from interested stakeholders (e.g. the scientific community, and policymakers) need to focus on defining CE in a more detailed manner, as well as its implementation at the different stages of production and consumption, especially in those operations for which no uniform approach or common practice can be established.

Whereas not all measures being implemented by the sampled companies directly lead to significant reductions in GHG emissions, they have an indirect effect, since the re-use of materials means that they do not need to be produced again, hence preventing new emissions from their manufacturing. This includes, for instance, producing chemicals that are themselves potent greenhouse gases. For example, hydrofluorocarbons are used as refrigerants and foam-blowing agents.

5.1 | Recommendations to industry

As this paper has shown, the chemical industry can play a key role in fostering a CE and in addressing one of the causes of climate change. Apart from the works being undertaken and documented in this paper, there is still much that it can do, beyond the operations of individual companies. For instance, the chemical sector may intensify efforts to develop new, high-performance chemical materials, such as smart coatings for glass, which may allow the sun's heat to be reflected or absorbed as needed, both in buildings and vehicles. In addition, the sector is well placed to address the need for using wood substitute materials in construction, such as polymers, which may help to avoid the environmental impacts of excessive tree felling. PVC, in particular, is one of the most valued materials in the construction industry due to its versatility and safety, which allows great savings in resources due to its high strength and durability. Microencapsulated paraffin cells have also been developed which, when incorporated into the walls, behave as a thermal absorber, absorbing heat as the temperature rises. This may reduce the need for using energy for cooling, an acute problem in the summer months.

Through the development of increasingly cleaner and more efficient technologies and processes, or through the generation of products that contribute directly or indirectly to the reduction of emissions, the chemical branch can be a key player in finding solutions to address the problem of global warming, hence contributing to a more sustainable world.

5.2 | Implications for policy and for governments

Policy-makers are kindly advised to place matters related to reductions from GHG emissions from the chemical sector more prominently in their agendas. The economic importance of the chemical sector and the fact that thousands of jobs are associated with it, suggest that measures such as fiscal incentives to promote more renewable energy in the sector and to remove the bureaucratic barriers associated with supply chains should be deployed. They may catalyse further optimisations which, in turn, may make the sector more competitive. This paper has also shown some implications to governments in the sense that they may also engage more in supporting the sustainability efforts from chemical industries, encouraging them to engage on R&D efforts with universities, leading to new types of products which may not only have a more efficient carbon footprint, but may also lead to viable alternatives to conventional chemicals. These may have new properties which may, for instance, reduce their impacts on biodiversity. Indeed, by implementing responsible practices, adopting cleaner technologies, investing in research and development, and adhering to environmental regulations, the chemical sector can minimise its impact on biodiversity and contribute to the conservation and sustainable use of natural resources.

5.3 | Contributions from the study and outlook

As the main contributions of this study, at a theoretical level, the advancement of the circular economy theme is highlighted by approaching it jointly with the theme of climate change, identifying pivotal elements in the trends and business practices of the chemical sector. On a practical level, it is worth mentioning the value of understanding the behaviour of these companies, which contributes to disseminating practices carried out in their operating context. At the social level, the understanding that the benefits of adopting circular practices favour positive socio-environmental impacts is highlighted. Additionally, regarding the policy level, understanding the environmental and adaptive practices in the sector provides important information to policymakers so that they can contribute to promoting a faster and more proactive, innovative, and sustainable transition through industrial policies.

With regards to the limitations of this study, the use of a single database for the bibliometric analysis of publications and analysis of data from reports and communications publicly disclosed by the companies stood out, which does not allow us to state that all company practices were presented here; nor does it make any generalisations possible, thereby restricting the results found for the companies investigated. Hence, for future research, we suggest expanding the databases and the cases analysed by observing different contexts and accomplishing quantitative research to consolidate the findings of this investigation. In addition, future research can include a deeper analysis of the contribution of circular economy strategies that must be conducted by the chemical sector and other resource-intensive sectors in order to achieve climate goals.

The implications of the paper to the theory of integration of climate change practices in a circular economy context, and under the perspective of chemical enterprises, are two-fold.

Firstly, chemical companies individually, or in collaboration with other industry players, may develop and adopt industry-wide sustainability standards and best practices. Secondly, by focusing on emissions reduction, sustainable product development, circular economy practices, and collaboration with stakeholders, they can make a positive impact on the environment while also securing a more sustainable future for their industry. Moreover, meeting and even exceeding regulatory requirements can help build a positive reputation and reduce their impacts on the environment and on the climate.

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ORCID

Walter Leal Filho https://orcid.org/0000-0002-1241-5225
Kamila Frizzo https://orcid.org/0000-0002-0858-7614
João Henrique Paulino Pires Eustachio https://orcid.org/0000-0002-6782-3904
Stella Tsani https://orcid.org/0000-0002-7302-4930
Pınar Gökçin Özuyar https://orcid.org/0000-0002-2505-2216

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