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The Circular Economy in Corporate Reporting: Text Mining of Energy Companies' Management Reports

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Abstract: This paper explores the implementation of the circular economy in the energy sector. The research findings contribute to our understanding of the practical application of the circular economy, enabling policymakers and stakeholders to make informed decisions and develop targeted strategies. The study analyzes 88 Portuguese companies' reports, examining the presence of circular economy strategies and initiatives. The results reveal that energy sector companies tend to prioritize reporting their greenhouse gas reduction efforts over their circular economy strategies. The findings align with previous studies in the oil and gas industry, emphasizing the significance of sustainability reporting and potential biases in reporting practices. The study also identifies a gap between circular economy terminology and its representation in reports, indicating the need for greater incorporation of circular economy-oriented initiatives in the energy sector. The research highlights the role of technology in fostering innovation and calls for strategic alliances and knowledge sharing to drive circular economy practices. Further research is recommended to understand the barriers to implementing circular economy practices and identify effective solutions. Overall, this paper provides valuable insights for advancing the circular economy in the energy sector and achieving broader sustainability goals.

Keywords: energy sector; circular economy; corporate reporting; text mining; VOSviewer

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1. Introduction

In 2015, the European Commission developed the first circular economy action plan to help stimulate Europe's transition toward sustainability. This plan has made companies more conscious of their role in the application of circular economy practices and inspired firms to disclose how they will take concrete action to contribute to meeting the European Union's (EU) ambitious objectives.

Energy resources are an especially important target in the cited action plan. For example, "bio-based materials can be used for energy uses (e.g., biofuels) and can contribute to the circular economy" (see section 5.5). Scholars have thus recently focused on how organizations can generate biofuel to contribute to the circular economy's growth [1,2].

The European Commission's action plan seeks to promote circular economy practices that can include, among others, accelerating circularity in renewable resources in terms of operational waste and decommissioning processes. Researchers have stressed that circularity is possible in not only material-related cycles but also investment in the large-scale development of renewable energy resources [3]. Energy companies are expected to pursue these projects in order to promote the circular economy, so they often disclose their contributions in management reports.

Greenhouse gases are the most common research topic when the energy sector is studied in this field, but recent investigations have also concentrated on exploring the circular economy's presence in EU energy companies [4]. Janik et al. [5] analyzed 61 sustainability reports issued by EU energy companies from 2018 to 2020, concluding that

these companies rarely mention initiatives related to the circular economy. Maia et al. [6] examined 26 electricity companies' reports from 2017 to 2019 and found that reuse practices have greater added value. Traxler and Greiling [7] observed that the electric utilities sector is progressing towards comprehensive, sustainable public value reporting, with private companies outperforming state-owned enterprises. Similarly, Slacik and Greiling [8] found that the coverage of triple-bottom-line indicators in the electric utilities sector is moderate, and public and non-listed companies have lower coverage rates compared to private and listed companies. Al-Shaer [9] concluded that companies that allocate more resources to produce high-quality sustainability reports tend to demonstrate a stronger commitment to overall quality. In line with this, Tsalis et al. [10] proposed a methodological framework for analyzing corporate sustainability reporting practices in alignment with the United Nations' Sustainable Development Goals (SDGs), highlighting the importance of assessing strategic initiatives and enhancing companies' accountability and transparency. These studies collectively emphasize the significance of sustainability reporting and its role in promoting transparency, accountability, and the pursuit of sustainable development goals within the electric utilities sector.

However, the literature on the circular economy in the energy sector is scarce and still in its infancy. In addition, these studies are usually limited by energy companies' publication of reports in their home country's language, so scholars tend to exclude reports from their sample when language standardization is unavailable [5]. These limitations have produced skewed results.

Embracing the circular economy paradigm enables managers to prioritize areas of focus, allocate resources effectively, and tackle challenges related to process improvement. This includes raising awareness, fostering collaboration and innovation, integrating circular principles, and facilitating performance monitoring and accountability. By aligning their strategies with the principles of the circular economy, managers can enhance the overall quality of their processes and drive sustainable growth.

To address these issues, the present study analyzed energy sector reports from multiple countries that were written in different languages in order to answer three research questions:

1. What clusters of circular economy terms appear in energy sector reports, and which clusters have been given the most attention?
2. To what extent is the circular economy present in energy sector reports?
3. What guidelines can future energy sector initiatives follow to ensure these companies implement appropriate circular economy initiatives?

The purpose of this work is to reveal the key themes addressed by managers through circular economy clusters identified in corporate reports. The circular economy clusters identified in corporate reports on the circular economy revealed the key themes addressed by managers. A critical analysis of the results provided a deeper understanding of the on-going debate about the circular economy's place in energy companies' action plans. Companies' reporting also needs to provide greater transparency about and accountability for the sustainability policies firms claim they have put into effect.

The text mining techniques applied in this study allow new insights for science based on the corpus of management reports analyzed and provide intuitive visualizations of the clustering results. The findings outline a conceptual framework for energy sector companies reporting on the circular economy and clarify the ways this business model has been applied or at least reported by firms. The results make a valuable contribution to the current search for the best ways to promote effective transparency and accountability in reporting related to circular economy initiatives. By identifying the key themes and assessing the level of circular economy integration, this study highlights gaps that should be addressed for companies to enhance their circular economy strategies and improve sustainability reporting. Moreover, this research emphasizes the importance of transparency and accountability in reporting. By analyzing energy sector reports, it provides insights into the level of transparency and the extent to which companies are held accountable for their circular economy efforts. This information is crucial for stakeholders, policymakers,

and investors who seek to evaluate companies' sustainability performance and support the transition towards a more circular and sustainable energy sector.

The paper is organized as follows: First, we provide a conceptualization of the circular economy and discuss the characteristics of the energy sector. The subsequent section details the materials and methods employed in the study, including data sources, data collection procedures, dataset characterization, pre-processing techniques, and text mining approaches. Next, we present the results, encompassing cluster profiles and the visibility of circular economy practices within management reporting clusters. This is followed by a comprehensive discussion of the findings, their implications, and concluding remarks.

2. Conceptualization of Circular Economy

The circular economy is a concept that is widely used in sustainability literature. Related studies have focused on recycling [11], reusing, and reducing practices [12]. Kirchherr et al. [13] conducted an extensive analysis of circular economy definitions and concluded that the circular economy is a combination of reducing, reusing, and recycling activities. The cited authors also report that this model specifies how businesses can operationalize and implement sustainable development.

Henry et al. [14] in turn carried out a literature review that revealed that the Ellen MacArthur Foundation [15] has the most cited collection of circular economy articles. This foundation's website divides the circular economy into three main areas: eliminating waste and pollution, circulating products and materials in both technical and biological cycles, and regenerating nature. Table 1 summarizes the terms used in reference to this model, according to the Ellen MacArthur Foundation [15].

Circular economy practices contribute to the achievement of sustainability goals, as they play a crucial role in transforming industries towards climate neutrality and enhancing long-term competitiveness. By adopting circular economy principles, significant material savings can be realized throughout value chains and production processes, resulting in additional value creation and unlocking economic opportunities.

However, the impact of these procedures needs to be measured with accurate indicators. Scholars emphasize the importance of identifying accurate measurement tools when evaluating circular economy initiatives' effectiveness [17]. These measures can be used by companies to assess the related performance. Indeed, according to Vitolla et al. [18], managers and academics have shown interest in the circular economy model, focusing on the implementation methods and communication strategies employed by companies to disseminate their circular economy and sustainability practices.

Thus, firms must systematically and consistently communicate, disseminate, and report circular economy practices to disclose information about sustainable procedures and their impact. The literature provides possible frameworks for reports, but the fields of non-financial reporting and sustainability have yet to formulate standardized reporting principles and methods for publishing data on circularity progress [19].

In the context of sustainability reporting, several widely recognized frameworks provide a basis for consistency and comparability. These frameworks include the Global Reporting Initiative (GRI), the Sustainability Accounting Standards Board (SASB), the Task Force on Climate-related Financial Disclosures (TCFD), and the recently proposed standards by the International Sustainability Standards Board (ISSB). The ISSB's proposed standards outline general sustainability-related disclosure requirements and climate-related disclosure requirements and build upon the recommendations of the SASB Standards. These standards are used to identify risks, opportunities, and appropriate disclosures related to sustainability issues until they are replaced by the Sustainability Disclosure Standards of the International Financial Reporting Standards (IFRS).

It is important to emphasize the integration of non-financial and sustainability information with financial reporting to provide a comprehensive view of a company's performance. This integration ensures transparency and balance in reporting and fosters stakeholder engagement. Consideration of various internal and external stakeholder perspectives is

crucial for obtaining a transparent and inclusive reporting process that allows stakeholders to feel a sense of participation.

Table 1. Circular economy lexicon and designated synonyms.

Term	Synonyms within This Study's Scope	Term	Synonyms within This Study's Scope
Circular economy	Circularity, linear economy, circular supplies	Regenerative production	–
Reuse	Reuse, reused, smart use	Remanufacture	–
Efficiency	Efficient	Repair	Repairability
Design	Eco-design, eco-design, circular design, innovative design	Reverse logistics	–
Renewable	–	Share	Sharing, shared, sharing platforms
Anaerobic digestion	–	Cross-cycle	–
Biological cycle	–	Recovery	Resource recovery
Composted	Composting	Product-as-a-service	PaaS
Durable	Durability, finite materials	Material Circularity Indicator	MCI
Lifetime	Lifetime, finite, end-of-life, lifespan, product life extension, end-of-life destination	Efficiency	Resource efficiency, efficient
Maintain	Maintenance	Biogas	Biofuel
Non-virgin materials	Virgin materials	Scarce	–
Recycle	Recyclability, recycling, recycled	Material	Materials, recourses, input
Redistribute	–	Global Reporting Initiative	Integrated reporting, GRI
Refurbish	Waste management, waste	Cradle-to-cradle	–
Risk	Material risk, scarcity risk	Share	Shared value, sharing
		Reverse	Reverse logistics

Source: Adapted from the Ellen MacArthur Foundation [16].

The GRI Standards, for instance, are regularly reviewed to align with global best practices in sustainability reporting. They enable organizations of all sizes and types to understand and report their impacts on the economy, environment, and society in a comparable and reliable manner. By adopting the GRI Standards, organizations can increase transparency and demonstrate their contribution to sustainable development. These standards are relevant to stakeholders, including investors, policymakers, capital markets, and civil society. They are classified as either Universal, applying to all organizations, or Sectoral, enabling sector-specific reporting on impacts [20].

Scholars further argue that sustainability could benefit from integrating the circular economy with recent technological innovations (e.g., cloud computing and the Internet of Things) [21]. Researchers have also suggested that most new technologies (e.g., blockchain) can contribute to improving circular economy practices [22]. It is important to highlight that establishing a direct link between reporting and the actual implementation of circular economy practices by companies is challenging, as noted by Falkenberg et al. [23]. The authors argue that while mandatory reporting regarding the circular economy is a potential avenue, it is necessary to consider the effectiveness of such reporting in driving actual implementation. However, Falkenberg et al. emphasize that additional reporting requirements can play a significant role in raising awareness of the circular economy and

increasing transparency. Moreover, it is crucial not to overlook the potential impact of reporting on the financial market, as it can influence investor decisions and promote circular economy practices.

3. The Role of the Energy Sector in Driving Sustainable Strategies

Achieving climate neutrality in the EU by 2050 is heavily reliant on the energy sector's efforts to reduce greenhouse gas emissions, with circular economy practices playing a crucial role alongside other initiatives. The International Energy Agency's [24] most recent report states that global carbon dioxide (CO_2) emissions from energy combustion and industrial processes rebounded in 2021 to reach their highest ever annual level. The energy sector thus continues to have a serious impact on the environment, which contributes negatively to climate change [25]. This sector needs to invest in renewable energy (i.e., solar, wind, hydropower, biomass, geothermal, and gravitational) instead of non-renewable energy (i.e., fossil fuels) [26]. The changes involved are collectively called the energy transition process, which is defined as a long series of initiatives that replace current fossil fuel-reliant systems with those using clean energy from renewable sources [27]. According to the Ellen MacArthur Foundation [28], current efforts to address climate change have primarily focused on the importance of renewable energy and energy-efficiency measures. However, achieving climate targets will also necessitate addressing the remaining 45% of emissions associated with the production of goods and products.

The circular economy plays an important role in companies' energy transitions given that its principles tend to be present when these organizations invest in green energy and reuse and refurbishment practices. The concept of clean energy embraces circularity goals when resources (e.g., sun, wind, biomass, and waste) are kept in the loop for as long as possible before disposal [29]. In this model, the energy sector needs to focus strongly on the United Nations' Sustainable Development Goals (SDGs). Clear practices are laid out in SDG documents, which are summarized in Table 2.

Table 2. Sustainable Development Goals (SDGs) for the energy sector.

SDG Number	SDG Denomination	Energy Sector's Potential Contribution
#7	Affordable and Clean Energy	Increase access to updated, reliable, and sustainable energy sources
#9	Industry, Innovation, and Infrastructure	Invest in research on and development of new renewable energy technologies and improved energy infrastructure
#13	Climate Action	Reduce greenhouse gas emissions and transition to low-carbon energy sources
#14	Life Below Water	Reduce marine pollution from oil spills and the use of fossil fuels contributing to ocean acidification
#17	Partnerships for Goals	Work with governments, non-governmental organizations, and other stakeholders to promote sustainable energy practices and achieve SDGs

Source: United Nations' SDGs.

Energy sector companies, therefore, should concentrate on and prioritize these sustainable practices and align their activities with the SDGs listed in the above table. To help these firms achieve this, scholars have explored how this sector applies circular economy concepts to its practices. Kalchenko et al. [30] concluded that the circular economy provides the energy sector with an approach that frequently focuses on resource efficiency. The latter goal can be defined as the designs, processes, and solutions that maximize the efficient use of natural resources to produce energy, including the end use of energy, excess energy, and side streams.

In terms of benefits, the literature shows that circular economy strategies stimulate creative transformation, reduce excessive primary resource use, support research and development, create jobs, and eliminate fossil fuel combustion waste [29]. Recent studies

have provided a better understanding of the energy sector's role in promoting sustainable practices. However, scholars emphasize that empirical research's contributions to mapping and furthering circular economy practices in this sector are still in the early stages [31].

4. Materials and Methods

The present study sought to define clusters of concepts in the energy sector's reports, so content analysis was conducted to extract and group the circular economy terms used by this sector's companies. The selection of the energy sector for this study was driven by several compelling reasons. Firstly, the energy sector occupies a pivotal position in the global economy, providing the necessary power and fuel for various industrial, commercial, and residential activities. However, this sector is also a significant contributor to environmental challenges, particularly in terms of greenhouse gas emissions and climate change impacts. Therefore, examining the circular economy's presence within the energy sector is crucial to comprehending its potential for promoting sustainable practices and identifying areas that require improvement.

Furthermore, energy policies and regulations, as exemplified by the European Commission's directives [32], place a strong emphasis on the integration of sustainable and circular practices within the energy industry. By conducting research on the circular economy in the energy sector, researchers can effectively evaluate the effectiveness of policy interventions aimed at driving sustainability and identify any gaps or challenges that need to be addressed.

For this purpose, the data for this study focused on analyzing companies' reports, particularly sustainability and management reports, as these documents often disclose information about circular economy concepts, corporate strategies, and sustainability initiatives. The decision to analyze companies' reports for this study is based on the understanding that these reports serve as a public disclosure platform for circular economy concepts and corporate strategies. Additionally, previous research [5] highlights the need for energy sector companies to prioritize circular economy actions in their reports and bridge the gap between intentions and operational implementation. By examining these reports, this study aims to gain insights into the energy sector's current approach to the circular economy and identify areas where improvements and greater attention to circular economy issues are needed.

The volume of data was considerable, which made using computer-assisted techniques more practical than carrying out a traditional manual systematic review. Previous research has found computer-assisted algorithms helpful, especially topic modeling or clustering algorithms [33]. The main advantages are faster text processing and no limitations on the amount of data [34]. It is worth highlighting that employing reports as the primary data source offers several advantages, including accessibility, transparency, and accountability. Analyzing reports allows for a comprehensive assessment of a company's circular economy practices, providing a holistic view of their initiatives, strategies, and progress. This approach ensures that relevant information is easily accessible and can be evaluated in a transparent and accountable manner.

The current study employed an exploratory methodology, which is valuable for generating new knowledge, gaining initial insights, identifying research questions, and uncovering gaps in existing knowledge. Exploratory research allows researchers to venture into unexplored areas, spark creativity, and establish a strong basis for future investigations. By adopting this approach, we were able to provide an in-depth understanding of the circular economy strategies and initiatives reported by companies in the energy sector. The results contribute to the expansion of knowledge in this field and pave the way for further exploration and discovery.

4.1. Data Source

The data collection phase followed two steps because of the large number of sustainability and circular economy-related reports published worldwide. The first was to

identify the firms to be covered by this research. The decision was made to restrict the research population to the companies listed in January 2023 on the website of Portugal's Entidade Reguladora dos Serviços Energéticos (ERSE) (Energy Services Regulatory Authority). This list can be accessed via the following link: https://www.erse.pt/eletricidade/funcionamento/comercializacao/ (accessed on 31 January 2023). The selection of these companies was based on various criteria, including the credibility and authority of ERSE, the availability of transparent information, and the representation of industry diversity. These criteria were deemed important in ensuring the reliability and comprehensiveness of the chosen companies for the study.

The second step was to collect the documents that contain texts focused on sustainability reporting, so the listed firms' websites were accessed. In some cases, portable document files (PDFs) could be downloaded from the website. In other cases, the websites displayed sustainability information. Appendix A lists the companies included in this sample as well as the data gathered for each organization.

4.2. Data Collection

Each firm's website was examined, and the respective information and documents related to sustainability were retrieved. When no information was found, the research team double-checked this result by searching through other websites that might have relevant documentation. For instance, some companies' reports were posted on the respective international group's website.

4.3. Dataset Characterization

The dataset included reports in PDF format in three different languages, as summarized in Table 3. Portuguese was the most common language. The documents' length varied between 100 and 210,000 words.

Table 3. Report language.

Language	Number of Documents	Percentage (%)
English	23	26%
Spanish	12	14%
Portuguese	53	60%
Total	88	100%

4.4. Pre-Processing of Data

This study used text mining tools because of the large dataset and the advantages provided by computer-assisted methods. A language standardization procedure was followed before processing the documents to obtain an English version of the reports. All the texts available only in Spanish and Portuguese were translated into English by Core Solutions' widely used translation software. In addition, optical character recognition technology was used with PDF documents to ensure their contents could later be recognized by the text mining software. OCR is a technique used to convert scanned or PDF documents into editable and searchable text. In this study, OCR was employed to extract textual data from the management reports obtained from the selected energy companies. The purpose of using OCR was to convert the reports into a format that can be processed by the text mining software, enabling further analysis and exploration of the content. By leveraging OCR, the study ensured that the textual information contained in the reports could be effectively utilized for text mining and subsequent analysis. This allowed for a more comprehensive examination of the circular economy strategies and initiatives implemented by the energy companies. These reports would otherwise have been ignored and excluded from the dataset.

4.5. Text Mining

This research relied on Orange3 (version 3.32) software's text mining tools and VOSviewer (version 1.6.19) software's clustering algorithm. Orange3 was especially important in the pre-processing phase. We chose to use the software Orange3 and VOSviewer in our study due to their proven reliability, flexibility, and wide range of applications in the field of text mining, as demonstrated in previous studies. First, content extraction was conducted using this software's text mining widgets, which facilitated the downloading of each document's content directly into a Notepad file. Second, this file was input into VOSviewer software, in which the content was analyzed for clusters using a minimum number of words according to their absolute frequency and greatest relevance in previous studies [35].

5. Results

The text mining technique produced five thematic clusters. Each cluster's words appear in that group's color on the VOSviewer word network graph (see Figure 1).

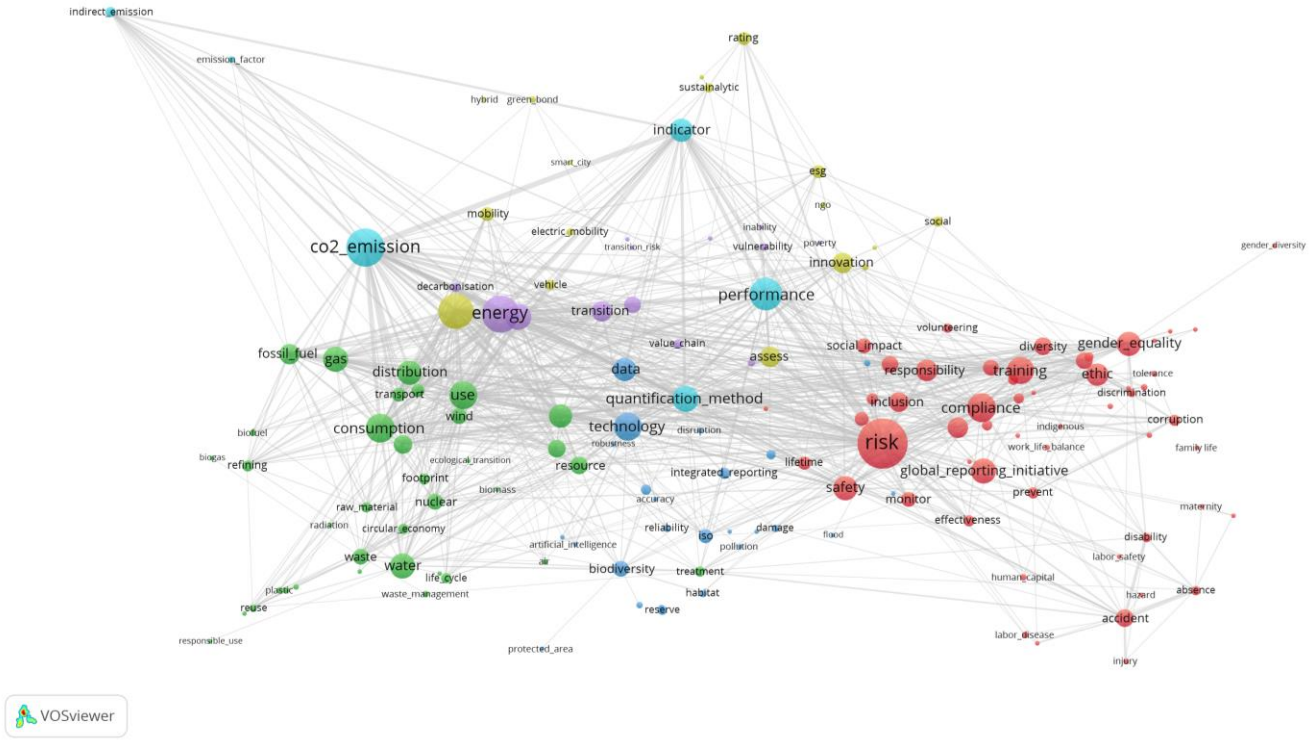

Figure 1. Clusters of terms in the VOSviewer co-occurrence map.

5.1. Cluster Profiles

The six clusters found in energy sector companies' documents are as follows: Cluster 1 Compliance Risk (red), Cluster 2 Resource Consumption (green), Cluster 3 Technology Transition (dark blue), Cluster 4 E-Mobility (yellow), Cluster 5 Renewable Energy (purple), and Cluster 6 Carbon Emission Measurement (light blue). Table 4 lists the most frequently used terms in each cluster and each term's number of occurrences.

Cluster 1, in red, is the most prominent group as it includes terms such as risk, compliance, and Global Reporting Initiative (GRI), which all appear the most frequently in reports. This cluster covers sustainability reporting initiatives in which human rights, labor issues, corruption, or terrorism are addressed. Companies describe their commitment to meeting GRI standards. For instance, one report discloses that the firm in question seeks to "embrace a culture free of prejudice concerning age, gender, origin, education, religion, disability, and sexual orientation" (Axpo).

Table 4. Cluster characterization.

Clusters	Terms	Number of Occurrences	Terms	Number of Occurrences
#1 Compliance Risk	risk	2841	volunteering	109
	compliance	938	absence	99
	training	850	discrimination	96
	Global Reporting Initiative	724	labor disease	60
	gender equality	686	human capital	59
	safety	659	violation	50
	ethic	573	injury	47
	responsibility	524	terrorism	41
	cooperation	474	tolerance	39
	inclusion	450	diligence	37
	diversity	380	work-life balance	36
	accident	375	hazard	34
	human rights	329	anticorruption	34
	SDG	314	maternity	31
	equality	305	violence	31
	social impact	277	indigenous	31
	monitor	268	motivation	28
	transparency	228	illness	26
	lifetime	202	labor safety	22
	local community	163	justice	22
	prevent	148	family life	20
	corruption	144	paternity	19
	effectiveness	140	dignity	17
	CSR	135	gender diversity	15
	integrity	121	civil society	15
	labor	119	compulsory labor	15
	child labor	116	decent work	11
	disability	113		
#2 Resource Consumption	consumption	972	life cycle	133
	use	891	raw material	132
	water	731	circular economy	117
	gas	712	reuse	63
	distribution	687	biofuel	60
	efficiency	641	plastic	57
	fossil fuel	496	waste management	50
	reduce	410	recycle	49
	resource	362	air	44
	solar	356	repair	35
	wind	309	radiation	31
	waste	309	biomass	26
	nuclear	292	radioactive waste	24
	transport	242	ecological transition	14
	green hydrogen	195	soil	14
	footprint	156	single use plastic	14
	refining	142	biogas	13
	treatment	135	responsible use	10
#3 Technology Transition	technology	923	forest	45
	data	635	disruption	37
	biodiversity	301	penalty	34
	ISO	243	artificial intelligence	32
	integrated reporting	160	pollution	25
	ecosystem	119	protected area	24
	reserve	100	accuracy	22
	continuity	99	weather event	20
	damage	69	responsiveness	18
	habitat	66	big data	15
	reliability	64	robustness	13
	bird	60	flood	12
	reputation	59		

Table 4. *Cont.*

Clusters	Terms	Number of Occurrences	Terms	Number of Occurrences
#4 E-Mobility	electricity	1454	electric mobility	66
	innovation	492	green bond	58
	assess	490	exclusion	53
	mobility	219	NGO	37
	ESG	195	green finance framework	
	rating	194	hybrid	31
	social	134	scrutiny	20
	vehicle	132	smart city	20
	Sustainalytics	97		10
#5 Renewable Energy	energy	1593	vulnerability	73
	renewable	759	inability	34
	transition	509	clean energy	27
	fund	318	poverty	25
	value chain	108	transition risk	15
	decarbonization	101	SME	12
	green energy	78		
#6 Carbon Emission Measurement	CO_2 emission	1633	indicator	605
	performance	1198	indirect emission	131
	quantification method	811	emission factor	56

Note. SDG—Sustainable Development Goal; CSR—corporate social responsibility; ISO—International Organization for Standardization; ESG—environmental, social, and governance; NGO—non-governmental organization; SME—small and medium-sized enterprise; CO_2—carbon dioxide.

Cluster 2, in green, includes terms related to energy consumption with a particular focus on different types of natural resources, both clean energy (i.e., water, solar, wind, biofuel, and biomass) and fossil energy (i.e., oil and fossil fuel). One company describes ongoing projects aimed at "produc[ing] sustainable aviation fuels from biomass" and "advanced biofuels for aviation, road, and maritime transport" (EDP). Other companies opt to include their ambitions, which are more like a vision than specific action plans being implemented. A report discloses how the firm in question seeks to achieve a total "use of power of wind, sun and water, [and] to be all green by 2030. . .[by] duplicating the capacity...[for] solar and wind power" (Cepsa).

This cluster also covers how organizations are managing the waste produced, but only high-level statements are included in reports. For instance, one document states that the operational plan includes practices that "prevent [the] production and the danger of waste [by] sorting, [finding] storage, and guarantee[ing. . .an] adequate final destination. . .[for the] waste produced" (Endesa). Another organization seeks to "maximize the recovery of waste and its reintroduction in[to] the economy as by-products" (EDP).

Cluster 3, in dark blue, comprises terms covering technological strategies and initiatives implemented by the energy sector to follow their climate transition plan. Some companies provide high-level comments about how they are using technology in their operations to promote sustainability. For example, a report observes that "new commerce value chains [were] enabled by. . .digitalization and artificial intelligence" (Cepsa). Other firms provide more in-depth, specific information.

Documents often detail how technology is supporting sustainable practices and provide project and partner names. For instance, reports contain descriptions of viticulture projects applying artificial intelligence algorithms to control trackers and adapt them to meet vineyard plants' physiological needs, optimize photovoltaic production, and collect data to measure humidity and temperature. Another document mentions how fruit trees are benefiting from artificial intelligence, which is being used to create more shade to "protect. . .plants from heat waves, droughts, hail, or frosts" (Iberdrola).

Cluster 4, in yellow, includes terms related to mobility. Organizations provide information on the measures implemented to improve energy efficiency, in particular by "boosting the consumption of mostly electric energy, including electric mobility" (Axpo). One firm

has proceeded with the "installation of charging stations for electric mobility [to] initiate changes to the car fleet. . .[that include adding] hybrid vehicles" (Capwatt).

This cluster is the first in which sustainability assessment indicators are mentioned by companies. Sustainalytics is considered a key rating organization that provides evaluations based on environmental, social, and governance (ESG) criteria. Companies proudly proclaim they have been designated as "top-rated" in terms of their ESG principles (Cepsa). Awards are also used by energy sector firms to instill confidence in their green bonds, namely, by reporting Sustainalytics's opinion that the firm in question "is credible, impactful, and aligned with the four components of the 2018 Green Bond Principles" (EDP).

Cluster 5, in purple, incorporates 13 terms with which companies discuss their climate transition and renewable energies' role in decarbonization. Firms provide a high-level discussion of risks, possibly because related vulnerabilities could be exposed. For example, an organization's report says that "transition risks may involve political, legal, technological, and market changes to meet climate change mitigation and adaptation requirements. . .[, namely,] financial and reputation risks" (Endesa). Although companies operate in a global market, one firm observes that "the main transition risks, [both] regulatory and market, are fundamentally national" (Iberdrola).

To address these risks, a company states that it sees its "commitment to the development of renewable energies" as a key risk-mitigation strategy. Energy firms are also investing in predictive modeling and smarter power banks, using machine learning, artificial intelligence, and big data to ensure better resource management practices (Iberdrola). One company prefers to emphasize that, despite the risks, it is aware of climate transition benefits, so it is working on "defining. . .[its] long-term ESG positioning and strategy. . .to leverage energy transition opportunities" (Cepsa).

Finally, Cluster 6, in light blue, includes six terms. Companies discuss methods they use to measure carbon emissions that are a result of their activities more accurately. Organizations mention various quantification methods, specific indicators, and performance measures. Companies also compare their activities' emission levels with EU companies' averages. This competitive perspective motivated one firm to provide quantitative data showing that its "power plants produce significantly fewer CO_2 emissions than the European average" (Axpo).

Organizations in this sector report that they follow national guidelines for measuring carbon emissions. These rules are provided, for instance, by the Department for Environment, Food, and Rural Affairs in the United Kingdom; the Rede de Transporte de Electricidade Nacional (Electricity Transmission Network) in Portugal; the Comisión Nacional de los Mercados y la Competencia (National Markets and Competition Commission) in Spain; or EU directives (e.g., biodiesel).

Companies usually conclude with an overview of their sustainability performance. They address this topic in sections labeled "Sustainable and Responsible Performance", "Climate Change Performance", "Environmental Performance", or "ESG Performance."

5.2. The Circular Economy's Visibility in Management Reporting Clusters

A term-by-term analysis revealed which circular economy practices are mentioned by firms. Table 5 lists the terms found in the six clusters identified by VOSviewer's algorithm in energy companies' reports.

Table 5. Circular economy terms found in company reports.

Cluster	Circular Economy Terms
#1 Compliance risk	Lifetime
#2 Resource consumption	Circular economy, reuse, efficiency, biofuel, recycle, repair, biogas, life cycle
#5 Renewable energy	Renewable, energy

First, only half of the clusters include circular economy practices. Clusters 3, 4, and 6 do not contain this type of word. Second, only 11 of the many possible terms were found. The term lifetime is mentioned in sections on compliance risk (i.e., Cluster 1). The co-occurrence of lifetime with other circular economy terms is tenuous. Lifetime appears, for instance, in reports of the improvements made by companies in end-of-life disposals of home network products put on the market.

The most prominent cluster with regard to applied circular economy practices is Cluster 2. Firms discuss their recovery and reuse of electronic equipment and these practices' evolution since the previous year. One company, for example, asserts that it is launching "new ranges of sustainable products, introducing for the first time renewable and recycled raw materials. . .[into these] products" (Cepsa). Organizations additionally describe how they are expanding their activities to include biogas, biofuels, and other bioliquids as new products.

Finally, reports mention circular economy practices that appear in Cluster 5. Energy companies refer to various services they provide in renewable energy, including the "installation, maintenance, and repair of renewable energy technologies" (Cepsa). Reports also include measures, disclose the amount of renewable energy generated, and provide details on types of energy.

Regarding the future, documents show how firms are taking "measures to improve energy efficiency and renewable energies", namely the amount invested in or revenue generated by renewable energy sales. Company reports mention innovative projects they support, such as renewable energy communities or renewable energy cooperatives (Coopérnico).

6. Discussion and Implications

The dearth of publications on the circular economy in the energy sector means that more research is needed on this topic. The few studies conducted thus far have confirmed that this sector's companies tend to report their initiatives and performance related to reducing greenhouse gases rather than their strategies to include circular economy practices in daily operations, products, and services. The present research's results also confirm that the circular economy is poorly represented in energy sector reports.

These results align with the conclusions drawn by Kwarto et al. [36], who conducted a comprehensive analysis of sustainability reports in the global oil and gas industry over an 11-year period. Their study emphasized the significance of sustainability reporting for upstream oil and gas companies, given the nature of their industrial operations and the importance of environmental management. While multinational companies in this industry may be motivated by ecological awareness or specific objectives such as reputation management and transparency, Kwarto et al.'s survey revealed potential biases in sustainability reporting due to the lack of triple bottom line implementation. These biases are associated with irregularities and fraud in Corporate Social Responsibility (CSR) practices. The findings of their research align with the Fraud Theory, which supports our study's observations of pressures that can lead to fraudulent practices. Additionally, Kwarto et al.'s study highlights the prominence of stakeholder theory, which explores how companies respond to stakeholder expectations in the implementation of CSR and sustainability reporting.

In addition, all the terms included in Table 1 above comprise the circular economy lexicon, but relatively few are used in reports. Only three of the six clusters identified in company reports include terms used by energy companies. This finding can serve as a starting point for reflection on how the energy sector can incorporate more circular economy-oriented initiatives.

Many relevant concepts were not found in the documents collected. For instance, firms commonly use gas cylinders to deliver gas to consumers in the gas distribution sector, which fell within the scope of the present study. Reusing and recycling these cylinders is important, so focusing on ecodesign principles could contribute significantly to efforts

to expand the circular economy and sustainability in this sector. The primary aim of the Ecodesign Directive is to encourage the development and manufacturing of energy-efficient products that minimize their environmental impact throughout their entire life cycle. This includes reducing environmental impacts during the use phase as well as during other stages such as manufacturing, distribution, and disposal. The directive encompasses a broad range of energy-related products, including household appliances, lighting products, heating and cooling equipment, consumer electronics, and industrial products [32,37].

The results underline ways that technology can be used to foster more innovation in the energy industry. Scholars argue that increasing innovation in the circular economy depends on forming strategic alliances [38], yet the term share was another circular economy concept excluded from the reports analyzed. Some companies are rather tentatively reporting cooperative initiatives that may facilitate knowledge and technology sharing to make the most of opportunities and develop innovations in the circular economy.

7. Conclusions

This study sought to understand the circular economy's place in energy sector firms' sustainability strategies and initiatives. To this end, 88 company reports were analyzed.

The transition of the energy sector towards a more sustainable and circular model is imperative for achieving global sustainability goals. The circular economy framework provides valuable insight into the progress made and the obstacles faced by the energy industry in adopting sustainable practices. By analyzing the circular economy's application in the energy sector, researchers can shed light on the successes, limitations, and innovative approaches employed within this critical industry.

The choice of analyzing reports instead of focusing solely on initiatives, company strategies, and action plans in this study offers several advantages. By examining reports, we gain access to a wide range of information, allowing for a comprehensive overview of the circular economy's presence in the strategies and initiatives of energy sector companies. The transparency and comparability provided by standardized reporting language further enhance our ability to analyze the data longitudinally. These factors collectively contribute to a more feasible and comprehensive examination of the circular economy's position within the energy sector's sustainable development efforts.

The research used methods that avoided the language limitations that have caused previous studies to exclude reports in other languages from their sample.

The content analysis identified six clusters in energy sector organizations' documents. These groups of terms were labeled as follows: Compliance Risk, Resource Consumption, Technology Transition, E-Mobility, Renewable Energy, and Carbon Emission Measurement.

The above results align with and reinforce previous findings in the literature, namely, that circular economy strategies and initiatives are still not included in energy sector organizations' reports. Some examples of circular economy practices have been adopted in this industry, but much room is left for improvement, especially if companies cooperate to share knowledge about innovative practices in this area. This gap must be filled to promote greater circularity in the energy sector and achieve broader sustainability goals.

This study's limitations included the fact that reports could not be obtained from some small and medium-sized enterprises in the energy sector. The analysis was thus restricted to the content available on larger organizations' websites, although, in some cases, no relevant information was found on these firms' sites. A concerted effort was made to identify and include as many energy sector companies as possible, but this limitation may have affected the results' comprehensiveness.

However, it is important to acknowledge certain limitations of this study. The analysis conducted in this research solely relies on text mining of management reports, which provides valuable insights into the communication of circular economy practices but does not directly capture the actual behaviors and outcomes of the companies. It is crucial to recognize that the implementation of circular economy principles goes beyond what is reported in these documents, and there may be discrepancies between reported intentions

and actual practices. Furthermore, the sample size of 88 management reports from energy companies may be considered relatively small, which could potentially limit the generalizability of the findings. Although efforts were made to gather information from the company websites, it was possible that some relevant data, such as sustainability reports, was not available or accessible through these sources. In such cases, additional measures, such as directly contacting the companies or exploring alternative reliable sources, could have been employed to obtain the missing information. This presents an opportunity for future research to consider alternative data collection strategies that involve direct engagement with the companies or exploring other reliable channels to ensure a more comprehensive assessment of the circular economy practices in the energy sector. Moreover, expanding the sample size to include a more diverse range of companies would contribute to a more robust analysis and provide a more accurate assessment of the circular economy's integration within the energy sector.

Further research could also contribute to accelerating this sector's progress in terms of circular economy practices. Scholars may obtain valuable insights by conducting in-depth exploratory work with selected firms to understand why these practices are not being applied and/or disclosed in their reports. This study could start by selecting specific circular economy practices that should already be present and conducting interviews with key stakeholders, such as those responsible for ESG initiatives, to better understand the barriers to implementation. As mentioned previously, a variety of circular economy practices are not being adopted by energy sector companies, and further research could shed light on why this has happened and what solutions work best to overcome this problem.

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Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found in the websites listed in Appendix A.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Sample of Companies and Respective Information Collected

Energy Sector Company	Website	Domestic Consumers	Big Consumers	Industrial Consumers	SME	Document Collected
ACCIONA Green Energy Developments, S.L.—Sucursal	Site	X	✓	✓	x	Consolidated Report 2021 (long report)
Ágoraluz Energia, Lda	Site	✓	✓	✓	✓	Website Print (short report)
Alfa Energia, Lda	Site	✓	X	✓	✓	Website Print (short report)
Audax Renovables, S.A.—Sucursal	Site	X	✓	✓	✓	Strategic Plan; Renovables Report; Website information; Growth Plan (long report)
Axpo Energia Portugal, Unipessoal, Lda.	Site	X	✓	✓	✓	Annual Report 2021; Holding report (long report)
A Eléctrica Moreira de Cónegos, C.R.L.	Not found	✓	X	X	x	Website print (short report)
Capwatt Retail Electricidade PT, S.A.	Site	X	✓	✓	x	Website print (short report)
Cepsa Gas y Electricidad, S.A.- Sucursal	Site	X	✓	✓	✓	Ethical code report; Climate Changes policies report; Strategy report for 2030; ISO 14064 report; Carbon footprint report 2021; Integrated management report 2021 (long report)
CLIDOMER Unipessoal, Lda.	Site	✓	X	X	x	Website print (short report)
Conquistas magnéticas, Lda.	Site	✓	✓	✓	✓	Website print (short report)
Cooperativa Eléctrica de Vale D'Este, C.R.L.	Site	✓	X	X	x	Not found
Coopérnico	Site	✓	✓	✓	✓	Website print (short report)
EDP Comercial—Comercialização de Energia, S.A.	Site	✓	✓	✓	✓	Sustainability report 2021 (long report)
Elergone Energia, Lda.	Site	X	✓	✓	✓	Website print (short report)

Energy Sector Company	Website	Domestic Consumers	Big Consumers	Industrial Consumers	SME	Document Collected
Endesa Energia, S.A.—Sucursal de Portugal	Site	✓	✓	✓	✓	Website print Sustainability Report 2017 (long report)
ENFORCESCO, S.A.	Site	✓	✓	✓	✓	Website print (short report)
ENI PLENITUDE IBERIA, S.L.U.-Sucursal em Portugal	Site	✓	✓	✓	✓	Website print (short report)
Ezurimbol—Comércio de eletricidade, Lda.	Site	✓	X	✓	✓	Website print (short report)
Fortia Energia, S.L.	Site	X	✓	X	X	Website print (short report)
Petrogal, S.A.	Site	✓	✓	✓		Integrated report 2021 (long report)
Goldenergy—Comercializadora de Energia, S.A.	Site	✓	✓	✓		Website print (short report)
G9Telecom, S.A.	Site	✓	✓	✓		Website print (short report)
Iberdrola Clientes Portugal, Unipessoal, Lda.	Site	✓	✓	✓		Sustainability report 2021 (long report)
JAFPLUS, Lda.	Site	✓	✓	✓		Website print (short report)
Logica Energy, Lda.	Site	✓	✓	✓		Service Quality Report 2021 (long report)
LUZBOA—Comercialização de Energia, Lda.	Site	✓	✓	✓		Service Quality Report 2015 (long report)
LusíadaEnergia, S.A.	Site	✓	✓	✓		Not found
MEO Energia—Comercialização de Energia, S.A.	Site	✓	✓	✓		Sustainability Report 2021; Sustainability Report 2020 (long report)
Multienergia Verde, S.L.—Sucursal em Portugal	Site	✓	✓	✓		Website print (short report)
Muon Electric, Lda.	Site	✓	✓	✓		Service Quality Report 2019 (long report)
Naturgy Iberia S.A.—Sucursal em Portugal	Site	X	✓	✓		Service Quality Report 2019 (long report)
On Demand Facilities, S.L.U.	Site	✓	✓	✓		Website print (short report)
Petrotermica Energia, SA.	Site	X	✓	✓		Website print (short report)
PlenoEnergia, Lda.	Site	✓	✓	✓		Website print (short report)
Portulogos Power, Lda.	Site	✓	✓	✓		Website print (short report)
Propensalternativa Unipessoal, Lda.	Site	✓	✓	✓		Service Quality Report 2021 (long report)
USENERGY, Lda.	Site	✓	✓	✓		Service Quality Report 2021 (long report)

Source: ERSE and authors.

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