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"Sustaining the Sustainable Sustainability": Leveraging Digitalization and Emerging Technologies by the Auditor in Providing Assurance on Sustainability Reporting

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Abstract

In today's rapidly evolving world, the importance of sustainability and circularity has become more prominent than ever. Businesses and economies worldwide are recognizing the need to transition towards a circular model, where resources are used efficiently and waste is minimized. This transition necessitates changes across all sectors, including financial auditing. While the main object of financial audit is to provide an opinion on financial statements to ensure that it gives true and fair view of the accounts, the auditor will also need to assess an organization's sustainability by evaluating its environmental and social impact, resource efficiency, and circularity performance. It becomes more and more important that the financial auditor should provide a comprehensive assessment of the organization's sustainability practices, enabling stakeholders to understand its commitment to environmental responsibility, social equity, and economic resilience. Auditing sustainability reporting involves different challenges compared to those encountered in auditing financial statements. The independent audit report issued by the financial auditor on sustainability reporting plays an essential role in building confidence in the robustness of non-financial information, providing benefits such as: ensuring the credibility of ESG information presentations within the annual report; creating a positive impact on the company's reputation; strengthening the company's awareness of material ESG risks and facilitating the improvement of internal systems, processes and controls and the company's performance in the ESG area; better positioning of the company in ESG rating rankings. Hence, auditing sustainability reporting goes beyond financial metrics and includes non-financial indicators that reflect the organization's triple bottom line – people, planet, and profit. Henceforth, by expanding the scope of financial audits to incorporate sustainability metrics, audit companies can demonstrate their commitment to the circular economy and provide transparency regarding their clients' environmental and social performance. Henceforward, auditing sustainability reporting not only enables stakeholders to make informed decisions, but also promotes accountability and incentivizes organizations to adopt circular practices. In this context, to effectively track, measure, and assess the sustainability performance of organizations, emerging technologies play a crucial role. This paper explores the role of emerging technologies in facilitating the transition of financial

auditing towards a circular economy by employing a Reflexive Thematic Analysis (RTA). Analyzing the literature on the subject is the first step in the process, which is followed by a reflective study of the underlying themes and their consequences for financial auditing procedures. Several important themes emerged, highlighting the benefits, difficulties, as well as moral and social ramifications of integrating modern technology. These themes draw attention to the topic's complexity and shed light on the opportunities and difficulties that come with incorporating emerging technologies into an audit engagement on sustainability reporting.

Key Words: *financial audit; auditing sustainability reporting; emerging technologies; ESG; sustainability; CSRD; digitalization; Blockchain; Internet of Things; Artificial Intelligence;*

JEL Classification: *M42, O14, O32*

1. Introduction

The global community is facing pressing challenges in the 21st century, including climate change, resource scarcity, and environmental degradation. As a result, there is an increasing urgency to transition towards more sustainable and circular economic models that prioritize resource efficiency, waste reduction, and environmental stewardship (Rockström *et al.*, 2009). The circular economy is gaining momentum as a framework that aims to decouple economic growth from resource consumption by promoting the reuse, recycling, and regeneration of materials and resources (World Economic Forum, 2014, 2019, 2021; Ellen MacArthur Foundation, 2015).

The EU Directive on Corporate Sustainability Reporting (CSRD, 2022/2464/EU) marks the most significant transformation in corporate reporting in the last 20 years. Companies are now evaluated not only from an economic-financial perspective, but also based on their commitments to ESG (Environment, Society, Governance), which need to be integrated into the business strategy and mission of an organization (Global Reporting Initiative, 2023). This leads to alignment with regulatory frameworks and the expectations of corporate information users. Implementing these requirements is essential in supporting the European Commission's stated objective of directing capital flows towards sustainable activities.

The directive provides for the disclosure of information on aspects such as the business model, strategy and related policies, key non-financial performance indicators and targets, company governance regarding sustainability aspects, assessment of double materiality, management of ESG risks and opportunities, as well as disclosures on environmental (including the European taxonomy) and social domains, in accordance with European sustainability reporting standards.

In this transition towards a circular economy, financial auditing plays a crucial role. Financial audits traditionally focus on assessing the accuracy, reliability, and transparency of financial information. However, in the context of a circular economy, and as regards auditing sustainability reporting, there is a need to expand the scope of financial auditing to include sustainability metrics, including ESG factors. ESG factors encompass environmental performance, social impact, and corporate governance practices. Incorporating ESG considerations into financial audits provides a holistic assessment of an organization's sustainability practices and enables stakeholders to make informed decisions.

To effectively track, measure, and assess the sustainability performance of organizations, emerging technologies play a vital role. Emerging technologies – i.e., Blockchain, the Internet of Things (IoT), Artificial Intelligence (AI), and renewable energy technologies (RET) – offer innovative solutions that can revolutionize the field of financial auditing (Deloitte, 2019). These technologies enable auditors to collect, analyze, and interpret sustainability data more effectively, providing organizations with valuable insights and recommendations for improving their reporting of the circularity performance and addressing ESG concerns. First, *Blockchain technology (BT)*, with its decentralized and transparent nature, ensures the integrity and reliability of auditing processes by creating an immutable and tamper-proof chain of transactional data (Teng *et al.*, 2021). The integration of BT in financial auditing enables auditors to verify the authenticity and traceability of sustainable practices – i.e., renewable energy generation and resource recycling (Farcane & Deliu, 2020; Tiron-Tudor *et al.*, 2021). Moreover, BT can enhance the transparency and accountability of ESG reporting by providing a secure and verifiable record of ESG-related data (Rejeb *et al.*, 2022). Second, *Internet of Things (IoT)* offers the capability to collect real-time data on resource consumption, energy usage, and waste generation

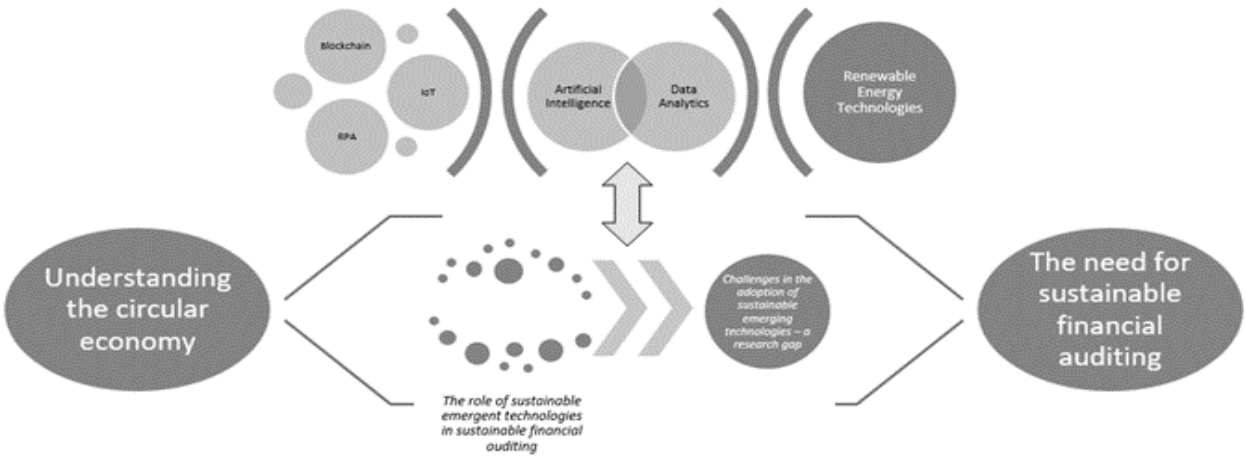
through interconnected devices and sensors (Zhou & Liu, 2022; Li *et al*., 2023). By utilizing IoT devices and Data Analytics, auditors can gain deeper insights and perform thorough analyses as regards an organization's circularity performance, as well as identify inefficiencies, and recommend improvements. IoT-based monitoring of ESG-related metrics (i.e., energy consumption, carbon emissions, and supply chain practices), enables auditors to assess an organization's adherence to sustainability goals and regulatory requirements (Bottaccioli *et al.*, 2017). Third, *Artificial Intelligence (AI) and Data Analytics (DA)* enable auditors to process and analyze large volumes of sustainability data, identifying patterns, anomalies, and correlations. AI-powered Data Analytics can automate auditing processes, making them more efficient and less prone to human error. Machine Learning algorithms can enable predictive modeling, allowing auditors to anticipate the impact of circular initiatives and simulate different scenarios (Dawid *et al*., 2017). By leveraging AI and Data Analytics, auditors can provide organizations with valuable insights on ESG performance and recommendations for achieving sustainable and circular business practices. Finally, the adoption of *renewable energy technologies (RET)* plays a crucial role in achieving a circular economy and addressing environmental concerns. Monitoring and evaluating an organization's renewable energy investments and energy efficiency improvements are essential for assessing their progress towards circularity goals. RET (i.e., solar and wind power), enable organizations to reduce their carbon footprint and reliance on fossil fuels.

In this context, it is obvious that the transition towards a circular economy necessitates an expansion of the scope of financial auditing to incorporate sustainability metrics and ESG considerations, in order to issue an audit report on the sustainability reporting of a company. In this context, emerging technologies – including BT, IoT, AI, and RET – may provide innovative solutions for collecting, analyzing, and interpreting sustainability data of the client company. By leveraging these technologies, auditors can effectively assess and track organizations' circularity performance, ESG performance, and provide valuable insights and recommendations for CSRD reporting, as well as for achieving sustainable and circular business practices.

2. Theoretical Background

This paper explores the existing research and studies on the role of these technologies in auditing sustainability reporting, respectively in in facilitating the transition of financial auditing towards a circular economy (***Figure no. 1***).

Figure no. 1. The contribution of emerging technologies to financial auditing's transition to a circular economy



Source: own projection

2.1. Understanding the Circular Economy

Before delving into the role of emerging technologies in financial auditing, it is important to have a clear understanding of the circular economy. The circular economy is an economic framework that aims to keep resources in use for as long as possible, extracting maximum value from them while minimizing waste and environmental impact. It promotes the design of products for longevity, the reuse and recycling of materials, and the regeneration of natural systems. Hence, it is a departure from the traditional linear economy, which follows a "take-make-dispose" model and relies heavily on the extraction of finite resources.

Hence, in a circular economy, products and materials are designed for longevity, durability, and repairability. The focus is on maintaining the value of resources throughout their lifecycle and promoting their reuse, recycling, and regeneration. Circular business models (i.e., product-as-a-service, sharing economy platforms, and closed-loop supply chains), are emerging as innovative approaches to enable the circular economy.

Henceforth, performing an audit engagement in the context of a circular economy requires new tools and approaches that align with the principles of sustainability and circularity. Traditional financial audits primarily focus on financial statements, balance sheets, and income statements. However, to capture the broader impact of organizations on the environment and society, especially as regards CSRD reporting, financial auditing must expand its scope to include sustainability metrics. This expansion calls for the integration of emerging technologies to effectively measure and evaluate an organization's circularity performance.

Henceforward, within this context, financial auditing plays a crucial role in assessing the financial implications and performance of organizations adopting circular economy practices. **Table no. 1** provides an overview of the existing research on financial auditing within the context of the circular economy, highlighting key themes, challenges, and potential opportunities.

Table no. 1. An overview of the existing research on financial auditing within the context of the circular economy and sustainability reporting

Criteria	Existing research
1. Financial Auditing Frameworks	Several studies have highlighted the need for developing auditing frameworks tailored to the circular economy. These frameworks should consider the unique characteristics of circular business models, i.e., product life extension, remanufacturing, and closed-loop supply chains (Ranta *et al.*, 2021; De La Cuesta-Gonzalez & Morales-García, 2022). Existing financial reporting standards may need to be revised to adequately capture the circularity of organizations' operations (Halari & Baric, 2023). Such frameworks should provide guidance on how to assess the financial implications of circular practices, value assets, and recognize the revenue streams associated with circular business models.
2. Performance Measurement	Financial auditing in the circular economy requires the development of new performance indicators that go beyond traditional financial metrics. They should assess not only economic performance but also environmental and social aspects, including resource consumption, waste generation, and social impact (Rodríguez-González *et al.*, 2022). Integrated reporting frameworks, such as the Global Reporting Initiative (GRI) and the Sustainability Accounting Standards Board (SASB), can provide a basis for holistic performance measurement (Rinaldi *et al.*, 2018). Integrated reporting encourages organizations to disclose their circular economy initiatives and their impacts on financial and non-financial performance, providing a comprehensive picture of their sustainability efforts.
3. Risk Assessment	Circular economy practices introduce new risks that need to be considered during audit engagements. These risks include material scarcity, regulatory changes, reputational risks, and extended producer responsibility (Okafor *et al.*, 2021; Talpur *et al.*, 2023). Auditors should assess the adequacy of organizations' risk management strategies and evaluate the integration of circularity considerations into their business models. The assessment of risks should encompass not only financial risks but also non-financial risks (i.e., environmental and social risks). This requires auditors to have a comprehensive understanding of the circular economy and its associated risks.

Criteria	Existing research
4. Data and Information Challenges	Audits engagements require access to reliable and relevant data. However, data availability and quality present significant challenges. Auditors may face difficulties in quantifying circular economy-related impacts and valuing non-traditional assets – i.e., waste streams and product residuals (Imoniana *et al.*, 2020; Di Vaio, 2023). Addressing data challenges and establishing standardized reporting mechanisms are essential. Organizations need to improve data collection and reporting systems to provide auditors with accurate and comprehensive information on their circular economy initiatives.
5. Assurance Services	Beyond financial audits, there is a growing demand for assurance services that provide stakeholders with independent verification of circularity-related information. Auditor's assurance can enhance the credibility and reliability of circular economy performance reports, allowing investors, customers, and other stakeholders to make informed decisions (Simnett *et al.*, 2009; Zadek *et al.*, 2021). Developing assurance frameworks specific to circular economy practices is an area that requires further exploration (van Dam *et al.*, 2020). Assurance providers can help auditors in evaluating the adequacy of circularity-related disclosures, assessing the reliability of data and information, and providing confidence to the stakeholders.

Source: own projection

Considering all this, financial auditing in the context of the circular economy and sustainability reporting presents unique challenges and opportunities. This literature review emphasizes the need for specialized financial auditing frameworks, new performance measurement indicators, comprehensive risk assessments, enhanced analysis of large volume of data, and the development of assurance services. Future research should focus on addressing these challenges and developing practical guidance for auditors in order to ensure the accurate and reliable reporting of sustainability initiatives.

2.2. The Need for Auditing Sustainability Reporting

Financial auditing is a critical process that ensures the accuracy, reliability, and transparency of financial information, providing stakeholders (i.e., regulators, and the general public), with confidence as regards the financial and non-financial reporting of organizations. However, in the context of a circular economy, traditional financial audits must evolve to encompass sustainability metrics.

Auditing sustainability reporting goes beyond the traditional focus on financial metrics and incorporates a broader set of indicators to assess an organization's environmental and social impact, resource efficiency, and circularity performance (Bebbington *et al.*, 2014). It recognizes that financial performance alone is not sufficient to capture the full picture of an organization's value creation and long-term viability. By integrating sustainability metrics into financial audits, organizations can demonstrate their commitment to the circular economy and provide transparency regarding their environmental and social performance. This expanded scope of financial auditing includes evaluating an organization's environmental practices (i.e., greenhouse gas emissions, energy consumption, and water usage) (KPMG, 2020, 2022). It also assesses the social impact of the organization, considering factors such as employee well-being, community engagement, and supply chain ethics (International Integrated Reporting Council, 2021). Additionally, the audit of sustainability reporting examines an organization's resource efficiency and circularity performance, including measures such as waste reduction, product life extension, and closed-loop material flows (World Economic Forum, 2014, 2019, 2021; Ellen MacArthur Foundation, 2015).

To effectively implement the audit of sustainability reporting, innovative technologies might play a crucial role. These technologies enable organizations to capture and analyze relevant data on sustainability metrics (Deloitte, 2019). Advanced DA, AI, and BT can enhance the accuracy and efficiency of data collection, verification, and reporting (World Economic Forum, 2019, 2021). By leveraging these technologies, auditors can access real-time and granular information, facilitating a more comprehensive evaluation of an organization's circular economy practices.

The audit of sustainability reporting serves several important purposes. Firstly, it enables stakeholders to

make informed decisions based on a comprehensive understanding of an organization's sustainability performance. Investors can assess the organization's alignment with environmental, social, and governance (ESG) criteria, integrating sustainability considerations into their investment decisions (Global Sustainable Investment Alliance, 2020). Regulators can monitor and enforce compliance with sustainability reporting requirements. Additionally, the audit of sustainability reporting promotes accountability by holding organizations responsible for their environmental and social impacts, encouraging them to adopt circular practices and improve their sustainability performance (United Nations, 2015).

In conclusion, expanding the scope of financial audits to incorporate sustainability metrics is essential in the context of a circular economy. The audit of sustainability reporting evaluates an organization's environmental and social impact, resource efficiency, and circularity performance, providing stakeholders with a comprehensive view of its sustainability practices. Innovative technologies are crucial for capturing and analyzing pertinent data, thereby enhancing the efficiency of sustainability reporting audits.

2.3. The Role of Emerging Technologies in the Audit of Sustainability Reporting

2.3.1. The Role of Blockchain Technology (BT) in the Audit of Sustainability Reporting

BT, with considerable potential to revolutionize various industries (Swan, 2015), holds significant promise for the audit of sustainability reporting. At its core, BT is a decentralized and distributed ledger that records transactions across multiple computers or nodes (Nakamoto, 2008). It provides transparency, immutability, and security by creating a tamper-proof chain of transactional data. These characteristics make BT a valuable tool for financial auditing, as it ensures the integrity and reliability of auditing processes and procedures.

Hence, by providing an immutable and transparent ledger, BT can enhance the trustworthiness of auditing processes (Crosby *et al.*, 2016). Additionally, it can enable the tracking and tracing of products and materials throughout their lifecycle, facilitating circular supply chains (Iansiti & Lakhani, 2017). Its decentralized nature ensures data integrity and reduces the risk of fraud.

In addition, BT enables the creation of smart contracts (Szabo, 1997) that can automate compliance and verification audit processes, ensuring that organizations adhere to circular economy principles. For example, a smart contract could be programmed to automatically verify the recycling or repurposing of a certain percentage of materials used by a company. This automation reduces the administrative burden on auditors and provides real-time visibility into circularity performance.

Moreover, BT can incentivize circular practices through tokenization and the creation of circular economy-based cryptocurrencies (Treiblmaier, 2018). These tokens can represent the value of sustainable actions (i.e., recycling or reducing carbon emissions), and can be exchanged or redeemed for goods, services, or financial benefits. By incorporating such tokens into financial audits, organizations can be rewarded for their circular initiatives, and auditors can assess and report on the impact of these actions accurately.

Several studies have explored the potential of BT in the audit of sustainability reporting. A study by Rejeb *et al.* (2022) examined the use of BT in verifying the authenticity and provenance of recycled materials. The study highlighted the potential of BT to provide a transparent and trustworthy record of recycling processes, enabling auditors to validate organizations' circularity claims (Fernandes *et al*, 2023). Similarly, da Cruz & da Cruz (2020) investigated the application of BT in tracking and tracing sustainable supply chains. They emphasized the role of BT in enhancing the visibility and accountability of circular practices, enabling auditors to evaluate organizations' adherence to circular economy principles.

Literature shows that BT has the potential to revolutionize financial auditing by providing an immutable and transparent ledger for verifying sustainability claims and tracking resource flows. However, further research is needed to address the scalability, interoperability, and privacy challenges associated with BT implementation in financial auditing (Farcane & Deliu, 2020; Tiron-Tudor *et al.*, 2021). Exploring the potential of BT-based platforms, developing industry standards, and establishing governance frameworks are areas that require attention to maximize the benefits of BT in the audit of sustainability reporting.

Therefore, the role of BT in the audit of sustainability reporting is significant. It offers advantages such as enhanced transparency, reliability, and automation of auditing processes, along with the potential for

incentivizing circular practices. By leveraging BT, organizations can improve the credibility of their sustainability claims and disclosures, auditors can efficiently assess circularity performance, and stakeholders can make informed decisions. Continued research and practical implementation are needed to fully realize the potential of BT in the audit of sustainability reporting.

2.3.2. Auditing in the Context of The Internet of Things (IoT) for Real-time Data Collection

IoT is another emerging technology that can contribute to the audit of sustainability reporting. IoT refers to a network of interconnected devices, sensors, and software that collect and exchange data (Atzori *et al*., 2010). IoT devices equipped with sensors can collect real-time data on resource consumption, energy usage, and waste generation. This data enables auditors to gain deeper insights into an organization's circularity performance, identify inefficiencies, and recommend improvements. IoT-powered systems provide accurate and granular data, enabling auditors to make data-driven decisions and measure the impact of circular initiatives effectively.

IoT devices can monitor resource flows (i.e., water, energy, and raw materials), at various stages of production and consumption (Rejeb *et al.*, 2022). This granular data allows auditors to assess the efficiency of resource utilization and identify opportunities for optimization. For example, sensors placed in manufacturing processes can provide real-time data on energy consumption, enabling auditors to evaluate energy efficiency measures and recommend strategies for improvement. By monitoring waste generation and implementing IoT-enabled waste management systems, organizations can also track their progress towards waste reduction and recycling targets (Iansiti & Lakhani, 2017).

Furthermore, the integration of IoT devices with BT can enhance the transparency and traceability of resource flows. By recording data from IoT sensors on a BT ledger, auditors can verify the authenticity and accuracy of the data, ensuring the integrity of circularity performance measurements. This combination of IoT and BT can enable auditors to track and trace the movement of materials, products, and waste, facilitating the implementation of circular supply chains and enabling the identification of potential bottlenecks or areas for improvement (Zhou & Liu, 2022; Li *et al.*, 2023).

Recent research has explored the potential of IoT in the audit of sustainability reporting. A study by Bottaccioli *et al.* (2017) investigated the use of IoT devices for monitoring and measuring energy consumption in buildings. The study demonstrated that IoT-based energy monitoring systems enable auditors to assess the efficiency of resource utilization and identify opportunities for improvement. Similarly, Cavalieri *et al.* (2021) examined the role of IoT in waste management for circular economy practices. They found that IoT-enabled waste management systems provide accurate data on waste generation and enable auditors to track organizations' progress towards waste reduction targets.

Hence, by integrating IoT devices with auditing processes, auditors can gain deeper insights into organizations' circularity performance and identify areas for improvement. However, challenges related to data security, interoperability, and scalability need to be addressed for effective implementation of IoT in financial auditing (Atzori *et al*., 2014). Further research is needed to develop standardized protocols, establish data privacy frameworks, and ensure the compatibility and interoperability of IoT devices and systems in the context of financial auditing.

2.3.3. Leveraging Artificial Intelligence and Data Analytics for the Audit of Sustainability Reporting

Artificial Intelligence (AI) and Data Analytics (DA) have the potential to revolutionize financial auditing by processing and analyzing large volumes of sustainability data. AI algorithms can identify patterns, anomalies, and correlations within the data, enabling auditors to uncover hidden insights and recommend improvements. AI-powered Data Analytics can automate auditing processes, making them more efficient and less prone to human error. By harnessing AI's capabilities, financial auditors can better assess the circularity performance of organizations and provide valuable recommendations.

Hence, AI-powered DA can help auditors detect non-compliance with circular economy principles and identify areas of improvement across the value chain (Bag *et al*., 2021; Roberts *et al*., 2022). By analyzing data from various sources (i.e., IoT devices, supply chain records, and financial statements), AI algorithms can identify inefficiencies, bottlenecks, or unsustainable practices. For example, AI can analyze energy consumption patterns

and recommend energy-saving measures, or it can assess the environmental impact of different suppliers and suggest more sustainable alternatives.

Machine Learning algorithms can also enable predictive modeling, allowing auditors to anticipate the impact of circular initiatives and simulate different scenarios. For instance, auditors can use AI models to assess the potential environmental benefits and financial implications of transitioning from a linear to a circular supply chain (Dawid *et al*., 2017). By leveraging AI and Data Analytics, financial auditors can provide organizations with valuable insights and recommendations to drive their circular economy strategies.

Various studies have explored the role of AI and Data Analytics in sustainability reporting (Bag *et al.*, 2021; Roberts *et al*., 2022). They investigated the application of AI in assessing organizations' circular economy performance, demonstrating that AI-powered Data Analytics can help auditors detect non-compliance with circular economy principles and identify areas of improvement across the value chain. Similarly, Dawid *et al.* (2017) examined the use of Data Analytics in evaluating the environmental impact of organizations. They found that AI algorithms can analyze sustainability data from multiple sources (i.e., IoT devices and supply chain records), to provide comprehensive assessments of organizations' circularity performance.

In conclusion, AI and Data Analytics have a great potential as regards enhancing the effectiveness and efficiency of the audit of sustainability reporting. By leveraging AI algorithms, auditors can gain valuable insights into organizations' circularity performance, assess the impact of circular initiatives, and provide recommendations for improvement. However, challenges related to data quality, privacy, and interpretability need to be addressed to ensure the accurate and ethical use of AI in financial auditing (Gandomi & Haider, 2015). Continued research and development in AI ethics, explainable AI, and data privacy frameworks are crucial for the responsible implementation of AI in the audit of sustainability reporting.

2.3.4. Impact of Renewable Energy Technologies (RET) on Financial Auditing

Renewable energy technologies (RET), such as solar and wind power, are integral to achieving a circular economy. These technologies enable organizations to reduce their reliance on fossil fuels and transition towards cleaner energy sources. The audit of sustainability reporting must consider the adoption and utilization of RET as a crucial metric for circularity. Monitoring and evaluating an organization's renewable energy investments and energy efficiency improvements are essential for assessing their progress towards circularity goals.

Financial auditors can leverage emerging technologies to assess and verify the adoption of RET by organizations. For instance, BT-based systems can provide a transparent and immutable record of renewable energy generation and consumption (Teng *et al.*, 2021). By recording data from renewable energy sources on a BT ledger, auditors can verify the origin and impact of renewable energy used by an organization. This ensures the accuracy of circularity performance measurements and provides stakeholders with confidence in the organization's sustainability claims.

Additionally, IoT devices can monitor and measure renewable energy generation in real-time. Smart meters and sensors installed in renewable energy infrastructure can collect data on energy production, storage, and consumption, enabling auditors to evaluate the effectiveness and efficiency of RET (Zhou & Liu, 2022; Li *et al.*, 2023). By combining real-time energy data with BT, auditors can ensure the integrity and transparency of renewable energy reporting, supporting the transition towards a circular economy.

In sum, RET play a vital role in the audit of sustainability reporting for the circular economy. Auditors can leverage technologies such as BT and IoT devices to assess and verify large volume of data regarding the adoption of sustainable practices.

2.4. Challenges in the Adoption of Emerging Technologies – a Research Gap

While emerging technologies offer immense potential, their adoption in financial auditing is not without challenges. Data privacy and security concerns, interoperability issues, and the need for standardized metrics are some of the key challenges to overcome. Additionally, there may be resistance to change and a lack of awareness and understanding of the benefits of these technologies. Addressing these challenges requires collaboration between technology developers, auditors, regulators, and businesses (***Figure no. 2***).

Figure no. 2. Key Considerations in Adopting Emerging Technologies for Financial Auditing

Source: own projection

Data privacy and security are critical considerations when implementing emerging technologies in financial auditing. As large amounts of sensitive data are collected and stored, it is essential to ensure that appropriate data protection measures are in place. Encryption, secure access controls, and anonymization techniques can help mitigate privacy risks (Iansiti & Lakhani, 2017). Moreover, auditors need to establish clear guidelines for data ownership, consent, and usage to build trust and protect stakeholders' interests.

Interoperability is another challenge that needs to be addressed. Different technologies and systems used for the audit of sustainability reporting must be able to seamlessly exchange data and communicate with each other. The lack of interoperability can hinder the effectiveness and efficiency of auditing processes, leading to fragmented and incomplete data (Rejeb *et al.*, 2022). Establishing standards and protocols for data exchange and integration is crucial to enable the interoperability of emerging technologies.

Standardization of metrics is essential for meaningful and comparable assessment of circularity performance across organizations. Currently, there is a lack of consistent and widely accepted sustainability reporting frameworks and metrics. Auditors and industry stakeholders need to collaborate to establish standardized methodologies and indicators for measuring and reporting circularity performance (Deloitte, 2019). This standardization will enable organizations to benchmark their sustainability efforts, facilitate comparisons, and drive continuous improvement.

Resistance to change and a lack of awareness and understanding are also significant challenges in the adoption of emerging technologies in financial auditing. Many organizations and auditors may be unfamiliar with the potential benefits and applications of these technologies. Education, training, and awareness

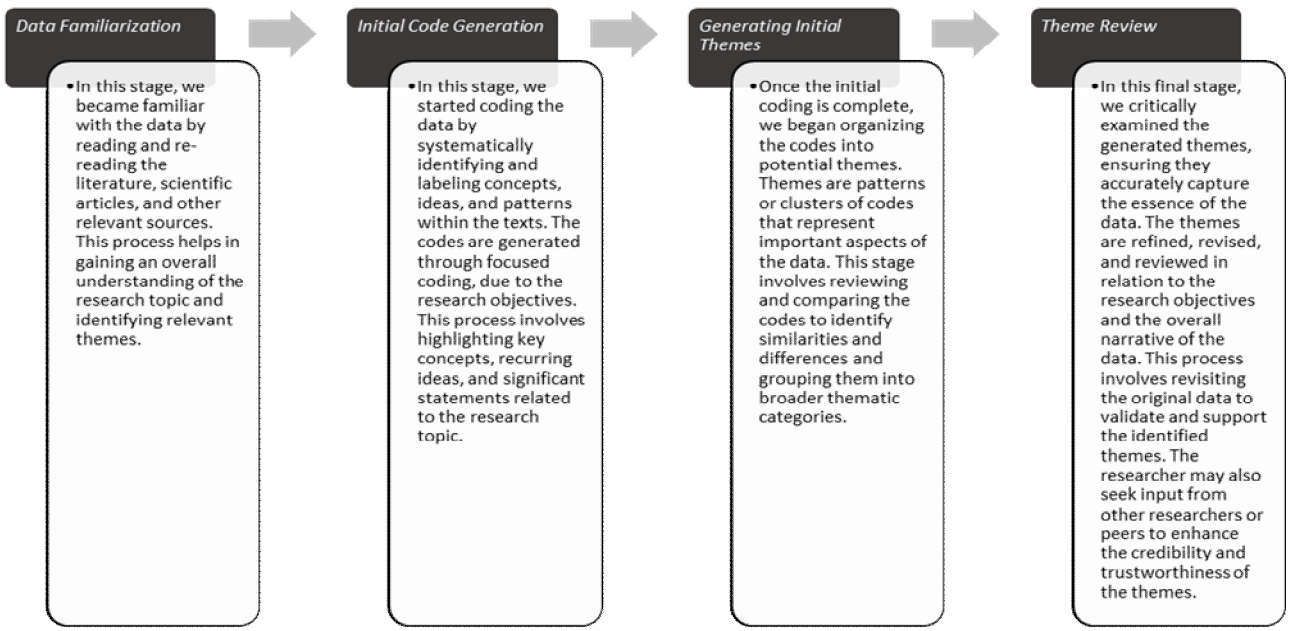
campaigns are necessary to bridge the knowledge gap and foster a culture of innovation and sustainability. Governments, industry associations, and academic institutions can play a crucial role in promoting awareness and providing support for the adoption of emerging technologies.

In a nutshell, while emerging technologies hold great promise for financial auditing in the context of a circular economy, there are several challenges that need to be addressed. Data privacy and security, interoperability, standardized metrics, and resistance to change are key areas that require attention. *Collaboration* between stakeholders, including technology developers, auditors, regulators, and businesses, is crucial to overcome these challenges and unlock the full potential of emerging technologies in financial auditing.

3. Research Methodology

In this *Reflexive Thematic Analysis (RTA)* we explore the role of emerging technologies in the transition of financial auditing towards a circular economy. The analysis involves an examination of the literature and research on the topic, followed by a reflexive exploration of the underlying themes and implications for financial auditing practices. RTA is a qualitative research method that allows for an in-depth exploration of themes and patterns within a dataset. It involves a systematic and iterative process of analyzing textual data to identify and interpret themes. It consists of four key stages: data familiarization, initial code generation, generating initial themes, and theme review (***Figure no. 3***).

Figure no. 3. RTA Method



Source: own projection

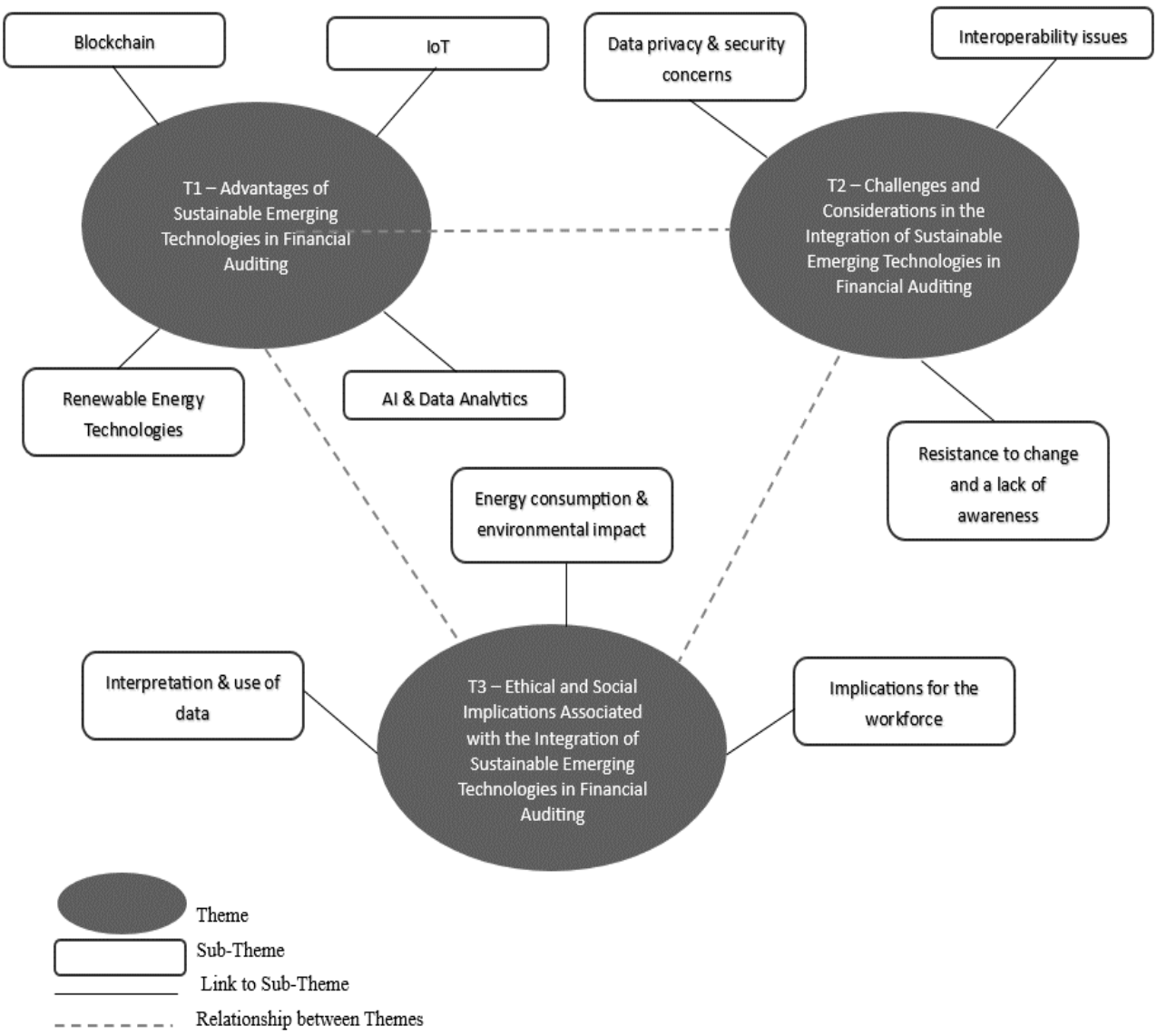
The RTA conducted in this study followed the methodology described above. The analysis involved a comprehensive review of the literature, including scientific articles, researchers' contributions, and practitioners' perspectives, to explore the role of emerging technologies in the transition of financial auditing towards a circular economy. Based on the RTA conducted on the literature related to this topic, several key themes emerged. These themes reflect the advantages, challenges, and ethical and social implications associated with the integration of these technologies.

These themes highlight the multifaceted nature of the topic and provide insights into the opportunities and challenges associated with the integration of emerging technologies in financial auditing for the circular economy.

4. Results and Discussion

The key points from the literature regarding the role of emerging technologies in the transition of financial auditing towards a circular economy are synthesized in *Figure no. 4* and **Table no. 2**.

Figure no. 4. Advantages, challenges, and ethical and social implications associated with the integration of these technologies



Source: own projection

Table no. 2. Key points from the literature regarding the role of emerging technologies in the transition of financial auditing towards a circular economy

Theme	Sub-Themes / Key points	References
1. Advantages of Emerging Technologies in Financial Auditing	- BT enhances transparency and traceability in circular supply chains.	Davradakis & Santos, 2019; Farcane & Deliu, 2020; Köhler & Pizzol, 2020; Menon & Jain, 2021; Okafor *et al.*, 2021; Tiron-Tudor *et al.*, 2021; Centobelli *et al.*, 2022; Rejeb *et al.*, 2022; Zhou & Liu, 2022; Fernandes *et al.*, 2023; Li *et al.*, 2023
	- IoT enables real-time data collection for accurate circularity performance evaluation.	Chen *et al.*, 2020; Cavalieri *et al.*, 2021; Wang *et al.*, 2021; Fernandes *et al.*, 2023
	- AI and DA provide insights into circularity performance and enable targeted recommendations.	Omoteso, 2012; Dawid *et al.*, 2017; Davradakis & Santos, 2019; Gepp *at al.*, 2018; Xing *et al.*, 2020; Bag *et al.*, 2021; Tiron-Tudor & Deliu, 2021; Roberts *et al.*, 2022
	- RET contribute to circularity and should be considered in financial auditing.	De Angelis, 2018
2. Challenges and Considerations in the Integration of Emerging Technologies in Financial Auditing	- Data privacy and security concerns must be addressed to ensure trust and confidentiality in the use of emerging technologies.	Iansiti & Lakhani, 2017; Alexandris *et al.*, 2018; Davradakis & Santos, 2019; Imoniana *et al.*, 2020; Tiron-Tudor & Deliu, 2022
	- Interoperability and standardization are necessary for seamless data exchange and consistent circularity performance measurement.	Atzori *et al.*, 2014; Paliwal *et al.*, 2020
	- Resistance to change and lack of awareness among stakeholders require education and training programs for successful implementation.	Tiron-Tudor & Deliu, 2022; Di Vaio *et al.*, 2023
3. Ethical and Social Implications Associated with the Integration of Emerging Technologies in Financial Auditing	- Environmental sustainability of technologies like BT and AI should be considered to balance benefits and environmental costs.	Munoko *et al.*, 2020
	- Ethical use of AI and responsible decision-making processes must be ensured in financial auditing.	Gepp *et al.*, 2018; Davradakis & Santos, 2019; Munoko *et al.*, 2020; Tiron-Tudor & Deliu, 2022
	- Workforce implications should be addressed through upskilling programs and social policies for a just transition.	Brenner, 2018; Kautz *et al.*, 2021; Tiron-Tudor & Deliu, 2022

Source: own projection

4.1. Theme 1: Advantages of Emerging Technologies in Financial Auditing

One prominent theme that emerged from the literature is the recognition of the advantages offered by emerging technologies in financial auditing for the circular economy.

BT, for instance, provides transparent and immutable ledgers that enhance the reliability and trustworthiness of auditing processes (Farcane & Deliu, 2020; Tiron-Tudor et al., 2021). It enables the tracking and tracing of products and materials, promoting transparency and accountability in circular supply chains. The use of BT in financial auditing has the potential to verify the authenticity of sustainability claims and ensure compliance with circular economy standards. BT having the potential to enhance transparency and traceability in supply chains, it can support the audit practices of sustainability reporting.

Hence, BT is used to create a decentralized and secure ledger of transactions, ensuring the accuracy and integrity of sustainability data (Köhler & Pizzol, 2020; Centobelli et al., 2022). Henceforth, BT has a vital role as regards enabling trust and reducing information asymmetry in financial audits, particularly in the context of sustainability reporting. Furthermore, research conducted by Davradakis & Santos (2019) explores the potential of BT-based smart contracts to automate auditing processes and enhance the efficiency of circular economy practices. By automating compliance checks and verification procedures, smart contracts powered by BT can facilitate real-time auditing, reduce errors, and provide accurate and tamper-proof auditing records (Farcane & Deliu, 2020; Tiron-Tudor et al., 2021). In addition, it is suggested that BT-based systems can facilitate the integration of multiple stakeholders in auditing processes, allowing for real-time data sharing and collaboration. This not only enhances transparency but also promotes accountability among participants in the circular economy (Menon & Jain, 2021; Okafor et al., 2021; Rejeb et al., 2022; Zhou & Liu, 2022; Li et al., 2023).

Similarly, the *IoT* offers real-time data collection capabilities that provide auditors with valuable insights into organizations' circularity performance. IoT devices equipped with sensors can monitor resource consumption, energy usage, and waste generation (Jin *et al.*, 2020), enabling auditors to identify inefficiencies and recommend improvements (Wang *et al.*, 2021). The integration of IoT with financial auditing processes enhances the accuracy and granularity of data, facilitating more informed decision-making in the pursuit of circularity goals (Fernandes *et al.*, 2023). Hence, IoT technologies have a great potential as regards real-time monitoring and measurement of energy consumption in buildings, enabling auditors to assess resource efficiency and identify areas for improvement. They emphasize the importance of IoT-based energy monitoring systems in capturing granular energy consumption data, allowing auditors to identify energy-saving opportunities and assess the effectiveness of energy management initiatives. Additionally, Cavalieri *et al.* (2021) highlight the role of IoT-enabled waste management systems in tracking waste generation and recycling rates, enabling auditors to evaluate organizations' progress towards circularity targets. Moreover, research by Chen *et al.* (2020) examine the use of IoT devices in tracking and monitoring the environmental impact of products throughout their lifecycle. Thus, IoT technologies can enable auditors to collect and analyze real-time data on product usage, maintenance, and disposal, providing insights into the circularity performance of organizations. Furthermore, IoT devices can provide auditors with valuable data on product lifecycles, enabling them to assess the extent to which products are designed for durability, repairability, and recycling. This data can inform auditing practices, allowing auditors to identify opportunities for improving the circularity of products and materials.

AI and DA have also emerged as crucial tools for the audit of sustainability reporting. AI algorithms can analyze large volumes of sustainability data and uncover hidden patterns and insights (Omoteso, 2012; Tiron-Tudor & Deliu, 2021). This enables auditors to detect non-compliance with circular economy principles, evaluate the impact of circular initiatives, and provide recommendations for improvement. The use of AI and Data Analytics in financial auditing promotes efficiency and accuracy in assessing organizations' circularity performance. Recent studies highlight the potential of AI in assessing circular economy performance and detecting non-compliance with sustainability goals (Bag *et al.*, 2021; Roberts *et al.*, 2022). They discuss the use of AI algorithms for analyzing sustainability data from various sources (i.e., financial records, supply chain data, and environmental monitoring systems). By leveraging AI techniques, auditors can gain deeper insights into organizations' circularity performance, identify areas for improvement, and provide targeted recommendations (Gepp *et al.*, 2018; Tiron-Tudor & Deliu, 2021). Similarly, Dawid *et al.* (2017) emphasize the use of Data Analytics in evaluating the environmental impact of organizations. They highlight the role of AI algorithms in analyzing sustainability data to provide comprehensive assessments of circularity performance, enabling auditors to identify environmental risks and opportunities for improvement. In addition, AI and Machine Learning techniques can be applied in analyzing financial data to assess organizations' circularity performance. AI algorithms can analyze financial statements, supply chain data, and sustainability reports to evaluate the circularity practices of organizations and identify areas for improvement (Omoteso, 2012; Xing *et al.*, 2020). AI-powered systems can assist auditors in conducting more efficient and accurate risk assessments related to circular economy practices (Davradakis & Santos, 2019). These systems can analyze vast amounts of data to identify potential fraud, non-compliance, or gaps in circularity strategies.

RET, likewise, play a pivotal role in financial auditing for the circular economy. Auditors need to consider the adoption and utilization of renewable energy sources as a metric for circularity performance. Monitoring and evaluating organizations' renewable energy investments and energy efficiency improvements are crucial in assessing their progress towards circularity goals (De Angelis, 2018). RET contribute to the reduction of fossil fuel reliance and promote sustainable energy sources, aligning with the principles of the circular economy. In this context, the impact of renewable energy investments on organizations' circular economy performance can be investigated. It is, therefore, important that the renewable energy investments of the organizations are taken into account, respectively it is vital to evaluate their progress in achieving circularity objectives.

4.2. Theme 2: Challenges and Considerations in the Integration of Emerging Technologies in Financial Auditing

Another key theme that emerged from the literature is the presence of challenges and considerations in the integration of emerging technologies in financial auditing.

Data privacy and security concerns pose significant challenges in the adoption of technologies such as BT and IoT. The collection and storage of sensitive sustainability data require robust data protection measures to ensure privacy and prevent unauthorized access (Iansiti & Lakhani, 2017). Addressing these concerns is essential to foster trust and confidence in the use of emerging technologies for financial auditing. For instance, Davradakis & Santos (2019) discuss the importance of data privacy and security in the implementation of BT, particularly in the context of financial audits. Tiron-Tudor & Deliu (2022) also highlight the need for secure access controls, encryption techniques, and data anonymization to protect sensitive information. In the same vein, Alexandris *et al.* (2018), as well as Imoniana *et al.* (2020), discuss the need for secure and privacy-preserving frameworks to enable the sharing and analysis of sustainability data. They emphasize the importance of auditors adopting encryption techniques, secure data storage protocols, and access control mechanisms to safeguard sensitive information.

Interoperability issues are another consideration in the integration of these technologies. Achieving seamless data exchange and communication between different systems and platforms is crucial for effective implementation. Standardization of metrics is also necessary to ensure consistent measurement and reporting of circularity performance across organizations (Paliwal *et al.*, 2020). Without standardized methodologies and indicators, comparisons and benchmarking become challenging, hindering the evaluation of circular economy practices. In view of this, Paliwal *et al.* (2020) emphasize the need for interoperability standards and protocols in the integration of BT and IoT technologies for the audit of sustainability reporting (Atzori *et al.*, 2014). They discuss the challenges associated with integrating heterogeneous systems and highlight the importance of developing common frameworks and standards to facilitate data exchange and collaboration between different stakeholders. The authors emphasize the role of auditors in advocating for interoperability and standardization efforts.

Resistance to change and a lack of awareness among organizations and auditors are additional challenges to be addressed. Many stakeholders may be unfamiliar with the potential benefits and applications of emerging technologies in financial auditing. Educating and raising awareness about the value and implications of these technologies are important for promoting their adoption and ensuring successful implementation (Tiron-Tudor & Deliu, 2022). Researchers, as well as practitioners emphasize the importance of education and training programs to help auditors understand and leverage emerging technologies effectively (Tiron-Tudor & Deliu, 2022). They discuss the need for continuous professional development to equip auditors with the necessary knowledge and skills. The authors highlight the role of industry associations, professional bodies, and academic institutions in providing training and support for auditors in the adoption of emerging technologies. Moreover, Di Vaio *et al.* (2023) suggest that auditors should engage in ongoing dialogue with stakeholders to address concerns, share best practices, and foster collaboration in the adoption of emerging technologies. They highlight the importance of auditors acting as change agents, driving the adoption of technologies and influencing stakeholders' mindsets and behaviors.

4.3. Theme 3: Ethical and Social Implications Associated with the Integration of Emerging Technologies in Financial Auditing

The reflexive exploration of the literature also revealed ethical and social implications associated with the integration of emerging technologies in financial auditing. While these technologies offer numerous advantages, it is crucial to consider their ethical implications and ensure responsible use.

For example, the use of BT raises concerns about *energy consumption and environmental impact*, given the computational power required for mining and verifying transactions. Balancing the potential benefits of these technologies with their environmental costs is a critical consideration in adopting sustainable practices. Hence, there is a stringent need to consider the environmental sustainability of BT and its impact on energy consumption. They discuss the challenges associated with the energy-intensive nature of BT and the need to explore energy-efficient protocols and consensus mechanisms. The authors emphasize the role of auditors in considering the environmental impact of technologies and advocating for sustainable practices.

Moreover, the use of AI and Data Analytics introduces ethical considerations related to the *interpretation and use of data*. Auditors must ensure transparency and fairness in decision-making processes and guard against biases and discriminatory practices (Gepp *et al.*, 2018; Tiron-Tudor & Deliu, 2021). Ethical guidelines and frameworks should be developed to ensure the responsible and ethical use of AI in financial auditing. Researchers discuss the ethical implications of using AI algorithms for decision-making processes in financial auditing (Munoko *et al.*, 2020, Tiron-Tudor & Deliu, 2022), also emphasizing the importance of ensuring transparency, accountability, and fairness in the development and deployment of AI technologies (Davradakis & Santos, 2019), thus highlighting the crucial role of auditors in considering the ethical implications of technologies and promoting responsible AI practices.

From a social perspective, the integration of emerging technologies has *implications for the workforce*. The adoption of these technologies may require new skill sets and capabilities among auditors. Training and upskilling programs should be implemented to ensure that auditors possess the necessary expertise to leverage these technologies effectively (Tiron-Tudor & Deliu, 2022). Additionally, the implementation of emerging technologies should be accompanied by measures to mitigate potential job displacement and ensure a just transition for auditors and other stakeholders. Brenner (2018) discuss the social implications of adopting sustainable technologies, emphasizing the importance of upskilling programs and social policies to support the workforce in the transition towards the audit practices of sustainability reporting. The authors highlight the role of auditors in fostering a supportive and inclusive environment during the transition and advocating for policies that promote job security and skill development. Furthermore, Kautz *et al.* (2021) suggest that auditors should consider the social impacts of organizations' circular economy practices, including aspects such as labor conditions, human rights, and community engagement. They emphasize the importance of auditors engaging with stakeholders to assess the social implications of circular initiatives and ensure responsible and ethical practices.

5. Conclusion

The transition towards a circular economy requires significant changes in various aspects of our society, including how an audit engagement aimed at providing assurance on sustainability reporting is conducted. Traditional financial audits primarily focus on financial statements and performance metrics, but in the context of such an engagement, there is a need for the auditor to expand the scope of auditing to include sustainability indicators. The audit of sustainability reporting evaluates an organization's environmental and social impact, resource efficiency, and circularity performance. This expanded scope calls for innovative technologies to capture and analyze the relevant data effectively.

Emerging technologies, such as BT, IoT, and AI, have the potential to revolutionize financial auditing by enabling the collection, analysis, and interpretation of sustainability data.

This RTA highlights the role of emerging technologies in the transition of financial auditing towards a circular economy. The analysis revealed the advantages offered by technologies such as BT, IoT, AI, and RET in enhancing transparency, real-time data collection, analysis of Big Data, and evaluation of circularity performance. However, challenges related to data privacy, interoperability, standardization, and awareness need to be addressed for effective integration.

The analysis also emphasized the ethical and social implications associated with the adoption of emerging

technologies. Responsible use, environmental considerations, and workforce implications should be considered to ensure the ethical and equitable implementation of these technologies. By understanding these themes and implications, stakeholders can make informed decisions and shape financial auditing practices that align with the principles of sustainability and the circular economy.

We observe, therefore, that the transition towards a circular economy necessitates the transformation of financial auditing processes. Emerging technologies play a vital role in facilitating this transition. By leveraging these technologies, auditors can collect, analyze, and interpret sustainability data and data referring to the non-financial performance more effectively, enabling organizations to measure and improve their circularity performance. However, challenges must be addressed to ensure the successful integration of these technologies into financial auditing practices. With continued innovation and collaboration, emerging technologies have the potential to drive the circular economy forward and create a more sustainable future for businesses and societies alike.

The literature on the role of emerging technologies in the transition of financial auditing towards a circular economy demonstrates the potential of BT, IoT, AI, and RET in revolutionizing financial auditing practices. These technologies offer opportunities for enhanced transparency, real-time data collection, and evaluation of organizations' circularity performance. However, challenges related to scalability, interoperability, data privacy, and standardization need to be addressed for effective implementation in financial auditing processes. Further research and collaboration between academia, industry, and regulatory bodies are necessary to harness the full potential of emerging technologies in financial auditing for the circular economy.

In conclusion, emerging technologies are catalysts for transforming financial auditing to support the circular economy. These technologies empower auditors to verify circularity claims, monitor real-time circular practices, analyze sustainability data, and ensure adherence to circular principles. As organizations strive to operate more sustainably and embrace circular practices, these technologies provide the tools needed to measure and drive progress. The role of emerging technologies in facilitating the transition of financial auditing towards a circular economy is fundamental in shaping a more sustainable and resilient future.

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