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Blockchain For Carbon Markets A Science Mapping Analysis of Digital Trust in Emissions Governance

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Abstract: This chapter reviews the use of blockchain in carbon markets as a digital trust infrastructure in the context of a bibliometric, science mapping review of 141 publications in Scopus 2018-2026. It determines some of the leading research trends, stakeholders, and themes within the field of blockchain-enabled carbon accounting and emissions governance. The results outline how blockchain can increase the level of transparency, traceability and accountability in any carbon trading system since the records are secure, tamper-resistant and can share information in real-time. Based on the analysis, key streams of research are evident as governance integration, market mechanisms, technological infrastructure, and sustainability applications. Although this has potential, such issues as scalability, regulatory uncertainty, and energy consumption remain. The paper offers a systematic review of the area and suggests the areas of future research concentrating on the incorporation or uniting of governance, technology, and sustainability to bolster the systems of the global market in climate change.

Index Terms - Blockchain, Carbon Markets, Carbon Accounting, Climate Governance, Science Mapping, Sustainability.

I. INTRODUCTION

Climate change has featured among the most critical concerns that the governments, institutions, and communities world over are addressing. The emergence of greenhouse gasses as well as the increase in the world temperature has necessitated international collaboration in order to reduce the effects of the climate change, hence creating the pathways to sustainable development process. In response to the foregoing concerns, policymakers have turned to the creation of the market-based instruments, e.g. the carbon markets to encourage organizations to reduce their carbon footprint. The carbon markets are rooted on the rule of trading carbon credits whereby the organizations trade carbon credits giving the impression that they are reducing greenhouse emissions. Carbon markets heavily depend on the accounting of carbon, as the process needs to be as transparent, as much as possible in terms of carbon accounting, verification etc. Various issues have been raised against the idea of carbon accounting, including the absence of transparency, inconsistency, the probability of promoting carbon credits, lack of traceability, etc., as mentioned by Andoni et al. (2019). This has compelled scientists to seek alternative technologies that can be used to improve the degree of transparency and accountability of the carbon markets.

During the recent years, blockchain technology has been recognized as a new technological innovation that may guarantee transparency, traceability, and trust within a digital system. Blockchain technology is a conceptualized system of distributed ledger that enables various stakeholders to store and authenticate transactions in a decentralized fashion. The advancement of this new technological tool has drawn considerable interest in the sustainability and environmental governance research because of its ability to

address some of the limitations of the traditional carbon accounting tool. As an illustration, blockchain can be used to guarantee capturing transactions in the carbon credit market in a safe way and make transparent trading of data between the regulators, organizations and verification bodies.

The initial research which has been conducted to investigate the concept of blockchain in the context of sustainability practices has revealed that it is useful in the enhancement of transparency and traceability in sustainability reports. Kouhizadeh and Sarkis (2018) demonstrated that the blockchain technology would be useful in enhancing sustainability reports by monitoring the environmental information in a trustful way. Moreover, Saberi et al. (2019) have demonstrated that the blockchain technology can be valuable to enhance the sustainable supply chain management based on enhancing the monitoring of environmental performance measures and delivering credible data of carbon emissions records. Such researches have demonstrated that blockchain-based technology can be useful in enhancing transparency in environmental governance by providing the sustainability information that can be easily traced and that cannot be altered.

Besides that, articles published in the domain of energy and environmental governance have also tried to learn how the blockchain technology can be utilized to facilitate transparency in the carbon trading and emissions monitoring systems. In their paper, Wu and Tran (2018) mention that blockchain technology can be proposed to facilitate decentralized energy systems and enhance the process of environmental information management. Casino et al. (2019) observe in another study that blockchain technology and its applications can help facilitate trust in the digital ecosystems because they are transparent and can't be affected by any interventions. There is the opportunity to implement blockchain technology into climate change governance to make sure the carbon credits are real and the threat of fraud and counting frauds is the least.

As the world has started to embrace carbon trading, researchers have started to consider the importance of blockchain technology in the process of carbon accounting and governance of emissions. The research has suggested that blockchain technology can improve the clarity of the global carbon trading market by ensuring recording the issuance and the trade of carbon credits is done without alteration. A research article by Chen et al. (2022) points out that blockchain technology can help in the process of monitoring, reporting, and verification by means of sharing data in real time by regulatory agencies, verification agencies, and market participants. This technology can foster confidence in the international carbon market because of the correct documentation of the success in cutting down carbon emission.

The emerging interest is reflected, however, in the number of research works on the use of blockchain technology in the area of climate governance, which, however, is dispersed in different areas of study, such as environmental economics, information systems, sustainability management, and energy studies. As much as research studies on the implementation of blockchain technology in the carbon trading sector have been high, fewer studies have exploited the intellectual framework and thematic trends of the topic. Nevertheless, to determine how this field of research has developed with time, it is worth applying methods of analysis that would be able to analyze a vast amount of academic literature and find the correlation between different substantial publications and research topics.

Bibliometric and science mapping methods can be considered effective tools to examine the development of a research domain and detach new thematic trends in a huge mass of academic papers. With the help of these methods, scholars could obtain the understanding of studying the networks of citations and co-authorship to visualize intellectual frame of a research area. According to Donthu et al. (2021), bibliometric methods are valuable when synthesizing a large amount of academic literature and as important research streams within an interdisciplinary domain of research. By applying such tools as science mapping (co-citation analysis, bibliographic coupling, and keyword co-occurrence analysis) researchers can obtain answers to the question of what happens to be the relation of various areas of knowledge or how topics of research develop with time.

RQ1: Which are the key trends of publications in research on blockchain and digital trust infrastructures in climate markets?

RQ2: What are the most active authors, institutions, and countries in this field of research?

RQ3: What are the major thematic groups in the work on the blockchain-based carbon accounting and emissions governance?

RQ4: What are the research directions that can be determined in future based on the existing literature?

II. REVIEW OF LITERATURE

In a more in-depth analysis of the chosen data set, one can note a gradual growing torrent of literature, exploring the nexus between blockchain technology, carbon markets, and climate governance. The results in the selected Scopus set of publications prove the rising academic interest in digital structures able to facilitate

clean and efficient climate markets. There is a large number of studies investigating the possible use of distributed ledger technologies in enhancing the integrity, transparency, and traceability of carbon accounting systems and emissions governance mechanisms. The current research uses a dataset acquired on Scopus which has peer reviewed articles on blockchain applications in climate market, carbon trading and sustainability governance 2018-2026. To guarantee that only the existing and high-quality studies were split, the dataset was narrowed down with the help of the PRISMA screening procedure (Moher et al. 2009).

The growing amount of literature is an indicator of the increase in the prevalence of digital trust infrastructures in resolving issues that are related to carbon accounting and emissions monitoring. Climate markets have a high demand of transparency mechanisms, accountability and verification through the carbon credit trading systems. Nonetheless, in a number of cases, the frameworks of carbon accounting have been discussed as having problems of outcome duplication, low transparency, potential data abuse, and lack of traceability (Andoni et al. 2019). Respondent to these issues, scientists have been taking a closer look at blockchain technology and how it will help enhance the efficiency and control of carbon markets.

In the early work in this field, the major emphasis was on the technical possibility of implementing blockchain into the energy systems and environmental monitoring. In particular, Wu and Tran (2018) presented the summary of blockchain implementation in sustainable energy systems and proposed that distributed ledger technologies would improve the transparency of data and the security of transactions in environmental markets. In their research, they noted the decentralized nature of blockchain that enables various stakeholders to access and share and authenticate environmental data with no central authority involvement. This aspect is of particular concern in carbon accounting schemes where there must be trust between participants in such a scheme.

As the climate policy frameworks were further elaborated, and internationalization of carbon markets was underway, the research interest eventually moved in the area of governance implications of blockchain based climate infrastructures. The article by Chen et al. (2022) looked at the potential of blockchain in the energy system and highlighted the possibility of enhancing environmental governance transparency and accountability. According to their findings, blockchain platforms have the potential to assist in the real time exchange of data between a regulator and market participants as well as verification agencies, which will enhance the processes of monitoring emissions and compliance.

A number of studies have also examined the utilization of blockchain technology in supply chains associated with the sustainability. Saberi et al. (2019) reviewed the role of blockchain in the operation of sustainable supply chain management and pointed to the ability to enhance environmental transparency. According to their study, the blockchain systems may make elaborate carbon emission monitoring across supply chains possible, and, therefore, the organizations will be more precise in evaluating the environmental effects of their operations. In the same way, Kouhizadeh and Sarkis (2018) also observed that blockchain-based systems of sustainability could enhance the integrity of environmental reporting and can contribute to validating sustainability assertions.

The studies in this field tend to point out that blockchain solutions have the potential to produce transparent and tamper resistant records of carbon related transactions. Casino et al. (2019) claimed that blockchain technology has the possibility to enhance trust in digital ecosystems due to the ability to have transparent and verifiable records of transactions. In the case of climate markets, this ability can assist in making sure that carbon credits constitute factual emissions lessening.

Zimba et al. (2025) also made a related contribution, conducting a systematic review on the topic of blockchain and energy efficiency. The role of blockchain as an enabler of secure and transparent infrastructure in the provision of environmental information is highlighted in their findings. The research marks that blockchain systems have the potential to support real time monitoring of emissions and can help the regulators to be more effective in checking whether the climate policies are met.

It further indicates that current studies report that blockchain registries of carbon might be effective in enhancing the transparency of voluntary carbon markets since records of carbon credit transacting remain indefeasible. These systems might be useful in discouraging any form of double counting as well as ensuring that every carbon credit is identifiable. Through this, the blockchain technology can make voluntary carbon markets more credible and submit to the involvement of additional businesses and investors.

Although there are emerging interest and appreciation of blockchain facilitated climate infrastructures, other studies also indicate the possible limitations and challenges. The information that is often discussed deals with the energy usage related to some blockchain consensus mechanisms. Overall, high-energy demands can become an environmental issue, especially when the technology of the blockchain is applied in the context of sustainability. To lessen the footprint of blockchain systems on the environment, researchers have thus

highlighted the need to come up with more energy efficient consensus mechanisms e.g. Proof of Stake consensus.

Table 1: Existing bibliometric studies on carbon markets.

Authors	Title	Year	Cited by	Data bases	Tools
Sharma, A.P.	Consumer's purchase behaviour and green marketing: A synthesis, review and agenda	2021	270	Scopus	Bibliometric Analysis
Donthu, N.; et al.,	A bibliometric retrospection of marketing from the lens of psychology: Insights from Psychology & Marketing	2021	228	Science	Bibliometric Analysis
Pittman, M.; Abell, A.	More Trust in Fewer Followers: Diverging Effects of Popularity Metrics and Green Orientation Social Media Influencers	2021	202	Survey data	Regression Analysis, SPSS/AMOS
Hudders, L.; de Jans, S.	Gender effects in influencer marketing: an experimental study on the efficacy of endorsements by same- vs. other-gender social media influencers on Instagram	2022	151	Primary survey	ANOVA, SEM
Zhou, X.; Yan.; et al.,	Making Sense? The Sensory-Specific Nature of Virtual Influencer Effectiveness	2024	150	Online survey data set	Structural Equation Modelling
Ooi, K.-B.; Lee.; et al.,	Social media influencers: An effective marketing approach?	2023	139	Scopus, science	Bibliometric Mapping
Li, H.; Lei, et al.,	Can you sense without being human? Comparing virtual and human influencers endorsement effectiveness	2023	126	Experimental Survey data	SEM, Regression
Johnstone, L.; Lindh, C.	Sustainably sustaining (online) fashion consumption: Using influencers to promote sustainable (un)planned behaviour in Europe's millennials	2022	120	Survey data	Regression Analysis, SPSS
Jacobson, J.; Harrison, B.	Sustainable fashion social media influencers and content creation calibration	2022	111	Content analysis dataset	Qualitative Analysis
Kapoor, P.S.; Balaji, et al.,	Greenfluencers as agents of social change: the effectiveness of sponsored messages in driving sustainable consumption	2023	100	Survey data	SEM
Jiang, K.; Zheng, J.; et al.,	Green power of virtual influencer: The role of virtual influencer image, emotional appeal, and product involvement	2024	93	Online survey	SEM
Kilipiri, E.; Papaioannou, E.; et al.,	Social media and Influencer Marketing for Promoting Sustainable Tourism Destinations: The Instagram Case	2023	85	Scopus	Bibliometric Analysis

Source: SCOPUS database and Author's compilation

2.1 Distinctive Contributions and Novelty

This study contrasts with the previous studies in a number of significant aspects. Firstly, where numerous available researches cover particular technological applications of blockchain to energy systems or trading arenas of carbon, the current paper has a wider viewpoint by accommodating blockchain as digital trust infrastructures within climate markets. This attitude allows exhibiting the role of blockchain technologies in enhancing transparency, accountability, and governance in climate market systems in a more thorough manner.

Second, the research uses both bibliometric performance analysis and science mapping methods to investigate the intellectual framework of research on this field. The study provides a structured review of how research on blockchain based climate infrastructures has changed over time by examining the trends of publications, influential authors, institutions, and clusters of topics.

Third, the research integrates science mapping and conceptual synthesis to gain further insight into the connections between the main research themes which include carbon accounting, emission governance, climate finance and digital trust infrastructures. This combined methodology goes beyond traditional literature reviews to include a quantitative bibliometric analysis and qualitative conceptual interpretation.

Fourth, the literature can be enriched by the study by shedding light on the emergent research themes and future research priorities in the study area blockchain enabled climate markets. The analysis through the analysis of key words co-occurrence and thematic mapping shows the following areas of development: decentralized carbon registries, blockchain-based climate finance, and integrating blockchain technologies with the Internet of Things based emissions monitoring systems.

Lastly, the research can be seen as an addition to the sustainability and green literature by accentuating the idea of using digital infrastructures to enhance global climate governance. With the current climate policy changes and investments in carbon markets, the need to create consistent digital systems will gain significance in promoting transparency, accountability, and trust among the parties concerned.

III. RESEARCH METHODOLOGY

3.1 Bibliometric Approach

The swift growth of the research studies of blockchain technology in the spheres of carbon accounting and emissions governance presupposes the necessity of systematic methods that would be able to organize the great amount of bibliographic material. There are bibliometric methods, which were initially formulated in the information science (Broadus 1987), which permit it to be structured and analyzed in terms of its output. This research utilizes two main methods, namely, performance analysis and science mapping (Donthu et al. 2021) following the methodological imperatives.

To supplement the quantitative mapping strategies, a Theory Context Characteristics Methodology (TCCM) framework (Clark et al. 1997) was used as an empirical synthesis of primary theoretical content, empirical context, and technological features and, finally, methodological strategy content in the literature. Besides this, the Entropy of all the keywords was also computed as normalized frequencies to have a measure of the thematic diversity over time in Shannon.

The parameters were standardized so that there would be methodological consistency. VOS viewer employed a minimum threshold of five co-occurrences of keywords, whereas Biblioshiny employed a method of fractional counting in analyzing co authorship. The methodological synthesis of the techniques can deliver a supplemental understanding of the structure, development, and thematic focus of the research on blockchain-enabled carbon governance.

3.2 Keyword Selection

The choice of keywords was performed in a systematic validation process. To begin with, ten open access studies on the blockchain use in the context of sustainability, carbon accounting and emissions trading were analyzed to determine commonly found and conceptually significant terms (Kouhizadeh and Sarkis 2018; Saberi et al. 2019; Dutta et al. 2020; Wang et al. 2021).

The initial list of keywords contained the following; blockchain, distributed ledger technology, carbon accounting, carbon markets, emissions trading system, climate governance, carbon credits, MRV, and sustainability reporting. Five domain experts in the domain of environmental accounting and climate governance assessed this first list to make sure that the list had an adequate coverage of the themes and there was alignment of the list with disciplinary requirements.

Following the feedback obtained, other governing and accounting related keywords such as the environmental management accounting, climate disclosure and green finance were added. Technological and governance dimensions were combined with the help of Boolean operators, e.g., search combinations of the form "blockchain" AND "carbon accounting" could be used. Data mining of the Scopus database was done with help of the validated keyword framework, which provided conceptual consistency between the

bibliometric analysis and the source of qualitative synthesis, and helped in making the study more rigorous methodologically.

3.3 Data Procurement

This research article is based on a systematic and repeatable data-acquisition approach to investigate how markets in the field of digital trust are built in climate markets, in more specific terms on blockchain facilitated carbon accounting and emissions regulation. The bibliographic database was accessed on the Scopus database that was chosen because it has wider coverage of peer reviewed articles that cut across interdisciplinary boundaries such as accounting, environmental governance and information systems.

In 2026 the search was carried out with the help of combinations of keywords, which were blockchain, carbon accounting, climate markets, emissions governance and digital trust infrastructures. The search query was narrowed down with the help of the Boolean operators and conceptual consistency of the query with the study goals. The search parameters were set to peer reviewed journal articles which were in English.

The first search resulted in 141 documents. Relevancy of these records was determined by screening the titles, abstracts and keywords. As the dataset was exported in Scopus without the merging of databases, no such thing as performing any duplicate removals was necessary. Relevance screening resulted in the inclusion of 141 distinct publications in the final dataset to be submitted to the bibliometric and thematic analysis based on their publications dating back to 2018-2026.

Search query : ((TITLE("Blockchain") OR TITLE("Distributed ledger") OR TITLE("Smart contract*") AND TITLE("Carbon credit") OR TITLE("Carbon footprint") OR TITLE("Carbon market") OR TITLE("Carbon trading") OR TITLE("Carbon offset") OR TITLE("MRV") OR TITLE("Sustainability accounting") OR TITLE("Climate finance")) AND (LIMIT-TO (PUBSTAGE,"final")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (SRCTYPE,"j") OR LIMIT-TO (SRCTYPE,"p") OR LIMIT-TO (SRCTYPE,"b") OR LIMIT-TO (SRCTYPE,"k")))

The data set created through this curation is the empirical underpinnings of the science mapping, bibliographic coupling and conceptual synthesis that were done in the study.

3.3.1 Inclusion–Exclusion Criteria

In order to avoid methodological transparency and analytical consistency, the Scopus dataset was narrowed down to a set definition of inclusion and exclusion criteria. The resulting criteria were aimed at ensuring peer reviewed studies that explicitly discuss blockchain applications in carbon accounting, carbon markets, and emissions governance, and screened out studies that did not fit the conceptual scope of the research.

The screening process was more conceptually oriented than based on mass filtering due to the targeted strategy (focused on a specific keyword) used to gather the set of the data and the fact that the information was directly exported out of Scopus. The use of these criteria enabled the maintenance of the final dataset of 141 publications to be closely related to the aims of this research.

3.3.1.1 Inclusion Criteria

The last dataset considered publications which satisfied the following criteria:

- Time frame: sources published in the Scopus database to the year 2026, which embodies the emergence of blockchain enabled sustainability research after preliminarily basic investigations (Kouhizadeh and Sarkis 2018; Saberi et al. 2019).
- Database source: Provided Indexing in the Scopus database in order to secure uniform metadata and citation searches as well as to identify authors.
- Type of document currently used: At the same time, peer reviewed journal articles and review papers are used to ensure academic rigor and comparability.
- Language: English language publications to guarantee some consistency on bibliometric analysis and qualitative interpretation.
- Topical relevance: Explicit mention of blockchain or distributed ledger technology as it applies to carbon accounting, carbon markets, or emission trading system or climate governance, environmental reporting, digitally relevant trust mechanisms, or digitally relevant climate governance.

The following inclusion parameters were put in place, so that the selected publications would play a direct role in comprehending how blockchain technologies can be used to enhance transparency and accountability in climate markets.

3.3.1.2 Exclusion Criteria

Publications were filtered out in case they fulfilled one or more of the following criteria:

- Included was any piece of research that only dwells on cryptocurrency, fintech, or blockchain architecture without that being related to sustainability of the environment and/or carbon governance.

- Technical studies of high technicality which did not go into governance, accounting or climate related implications.
- Non research literature includes editorial reviews, book reviews, notes or brief commentaries. Records, which have no full bibliographic details or have absent abstracts.
- Articles where blockchain or carbon markets have been mentioned only once without any serious analysis.

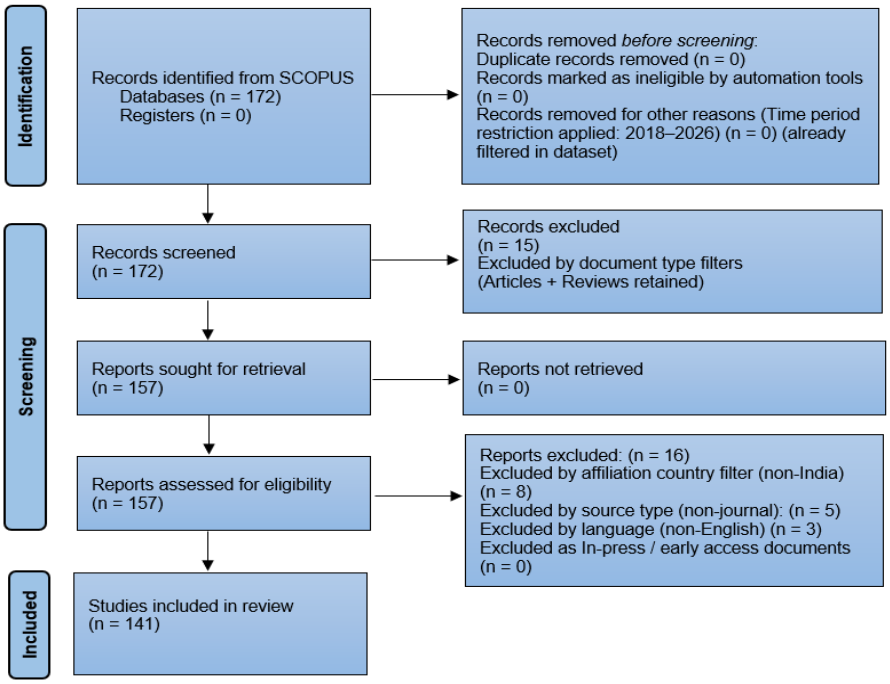

Figure 1: PRISMA Flow Diagram

PRISMA is the abbreviation which means Preferred Reporting Items in Systematic Reviews and Meta-Analyses. It was brought about by David Moher and others in the year 2009.

It gives the guidelines on how to report systematic reviews, and it contains the PRISMA flow diagram, which it utilizes in the selection of studies.

The use of these exclusion criteria guaranteed clarity of the concept and allowed reaching a final dataset of 141 publications which constitutes the empirical input of the bibliometric and content analysis done in the present research.

The systemic application of these criteria narrowed the starting 141 documents to 26 eligible publications, as can be seen in the PRISMA flow diagram (Figure 1).

3.4 Content Analysis and Construction of Future Agenda

Having transcended the processes of the bibliometric performance analysis and science mapping, the final dataset of 141 publications was to be reviewed using structured content analysis. The rationale of the stage was to distinguish popular theoretical views, empirical situations, methodology, and subsequent research of the research area, namely, blockchain-enabled carbon governance.

The process of identifying recurring themes in the literature was performed through a manual coding. These themes were digital trust infrastructures, transparency of carbon registry, automation of measurement reporting and verification system, tokenized carbon credits, enabling smart contracts in emissions trading and regulatory interoperability in climate governance.

Themes that were used more than once in different studies or were addressed in literature case authors of high reference levels like Kouhizadeh and Sarkis (2018) and Saberi et al. (2019) were kept. The importance of these foundational works was that they had a great conceptual impact on subsequent streams of research.

In order to have the results arranged in a systematic way, Theory Context Characteristics Methodology (TCCM) framework (Clark et al. 1997) was used. This structure allowed categorization of important areas of the literature, which include theoretical underpinnings, empirical settings, technological peculiarities and research methodologies.

IV. RESULTS

4.1 Science Mapping

A science mapping analysis of the current state of research at the intersection of blockchain and climate markets was performed using VOSviewer to investigate the intellectual structure, thematic development, and emerging directions of research. Some of the bibliometric methods were used in this analysis, such as co citation analysis, bibliographic coupling, and mapping of co-occurrence of key words. Such practices can be

used to determine the knowledge bases of the discipline, existing research communities, as well as the conceptual frames that are informing the digital infrastructures of carbon accounting and emissions governance.

Science mapping can enable the analysis to go beyond a descriptive review because it uses visualization to understand how authors, publications, and key concepts relate to each other. Rather, it offers an organized insight into the conceptualization, application and integration of blockchain technologies into climate markets systems.

4.2.1 Co citation analysis

The use of co-citation analysis demonstrates the knowledge framework and background of the research of blockchain in carbon accounting and climate governance. The analysis suggests that the studies that are commonly cited all centre around the use of blockchain to improve transparency, traceability and trust in carbon markets and system of emissions reporting. The fundamental knowledge base is represented by seminal works, including Andoni et al. (2019), Saberi et al. (2019), and Casino et al. (2019) and indicates the combination of blockchain with the sustainability and energy systems. Clusters that form out of the co-citation network indicate the major thematic aspects which include the carbon trading mechanisms, supply chain sustainability as well as climate finance. Also, there are good co-citation connections indicating interdisciplinary convergence between information systems, environmental science, and energy economics. The fact that there are recent works in the field suggests the growing research field with the escalating scholarly interest. In general, the trends of co-citation show that the conceptual debates are giving way to application and governance-based studies of digital climate infrastructures.

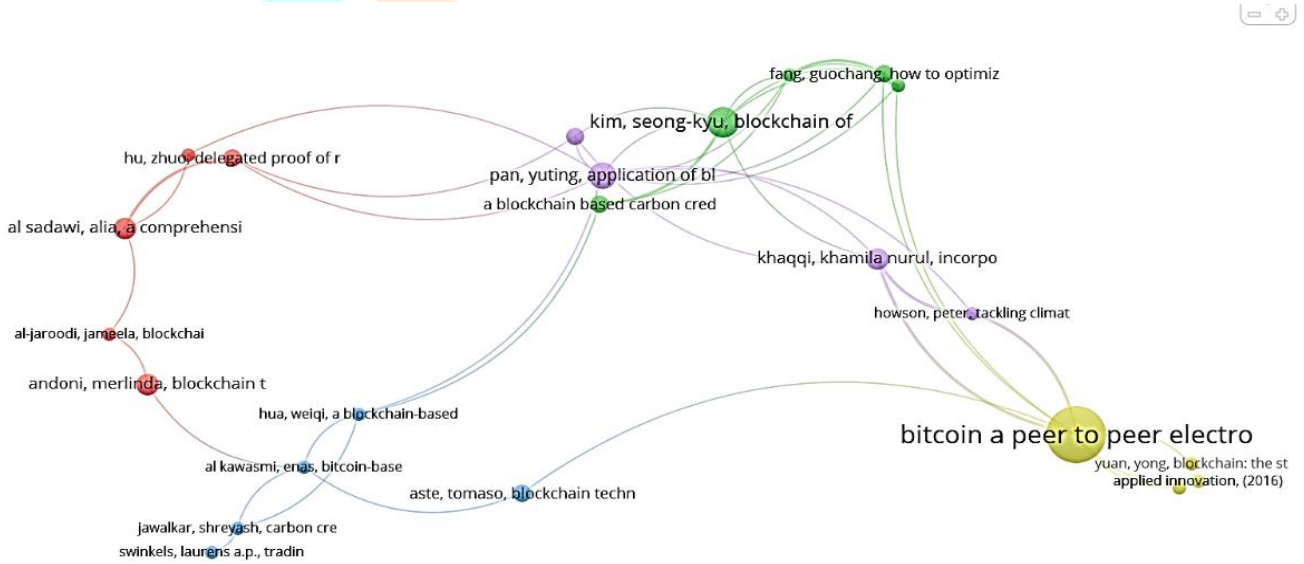

Figure 2: Co-citation analysis; **Source:** VOSviewer.

Intellectual Structure of Digital Trust Infrastructures in Climate Markets

The integrated citation analysis of eleven knowledge clusters interconnected develops a description of the intellectual construct of blockchain facilitated digital trust infrastructures of carbon accounting and emissions governance. These clusters depict how innovative ideas of blockchain have increasingly intersected in the sphere of environmental economics, carbon market design, energy systems and regulatory governance. This has led to the multi layered research space that has arisen in the literature to combine the aspects of technological innovation and aims towards climate governance.

Cluster 1: Carbon Footprint, Supply Chains, and Low Carbon Operations

This cluster will unite the fundamental research works working on the carbon footprint measuring process, the model of emissions and the low carbon operating policies. Initial input explores the approaches to measuring the supply chain emissions and ways of operating to curb carbon emissions (Benjaafar et al., 2013; Bottcher et al., 2015). More current studies propose blockchain made traceability solutions that enhance the quality and auditing of carbon footprint data (Rosado da Cruz et al., 2020; Fernando et al., 2021). This group forms the basis of measurement on which digital carbon market trust infrastructure is composed.

Cluster 2: Foundational Blockchain Economics and Distributed Trust

Based in Nakamoto Bitcoin: A Peer-to-peer Electronic Cash System (2008), this cluster demonstrates the original idea on the conceptual and economical background of blockchain technology. The main contributions consider blockchain as a decentralized coordination mechanism to sample trust without central control. The principles that are emphasized by these studies include minimization of trust, verification through incentives, and cryptographic verification (Tapscott and Tapscott, 2016; Beck et al., 2017). The cluster determined the

theoretical reasoning of decentralized trust later sustaining blockchain applications within climate market systems.

Cluster 3: Carbon Markets, Environmental Policy, and Emissions Governance

Cluster 3 deals with the topic of carbon trading systems, environmental effectiveness of the policies, and institutional forms that control the world of emissions markets. Other studies discuss the emission trading schemes in such areas as the European Union and China along with international ailments like the Kyoto Protocol (Almer and Winkler, 2017; Cong et al., 2017; Xiong et al., 2017). In this regard, blockchain technology is addressed as a means that can enhance governance by enhancing monitoring, reporting and the verification procedures of controlled carbon markets (Franke et al., 2020; Richardson and Andres, 2020).

Cluster 4: Blockchain Enabled Emissions Trading Systems and Consensus Design

This cluster is an array of technological architectures that are intended to support blockchain based carbon trading systems. Scholarly research investigates authorisation of blockchain networks, smart contracts and other consensus protocols that facilitate effective carbon trading systems. To improve scalability and institutional compatibility, scholars have suggested a number of models such as reputation-based consensus mechanisms, blockchain of things architectures, and cross chain trading frameworks (Hu et al., 2020; Al Sadawi et al., 2021; Muzumdar et al., 2022). The cluster indicates the growing interest in dedicated blockchain solutions having climate governance systems in mind.

Cluster 5: Blockchain Adoption, Socio Technical Transformation, and Sustainability

Cluster 5 looks at blockchain as a more general socio technological change that has the potential to be used to promote sustainability transitions. The research studies on the barriers to the adoption of blockchain, institutional transformation processes, and the prospect of blockchain technologies in advancing the Sustainable Development Goals (Andoni et al., 2019; Aste et al., 2017; Dorf Leitner et al., 2021). Instead of attempting to consider blockchain solely in terms of carbon markets, the following studies frame the notion of blockchain in broader frameworks of green finance and sustainability efforts.

Cluster 6: Blockchain Based Carbon Credit Systems and Market Transparency

This group is concerned with applied research on blockchain applications on carbon credit markets. Among the main issues, there are carbon credit tokenization, peer to peer trading platforms, and enhanced transparency in carbon transactions. Scholars suggest decentralized systems to issue, transfer, and verify carbon credit, and the move towards more automation and less fraud risk should be considered (Al Kawasmi et al., 2015; Chakraborty et al., 2022; Jawalkar et al., 2024). These works point at the potential to use blockchain as a way through the lack of trust that is frequently experienced in the voluntary markets of carbon trading.

Cluster 7: Cross Border Carbon Markets and Legal Institutional Interfaces

Cluster 7 focuses on legal and regulatory issues related to conducting carbon markets in different jurisdictions. Treatises are looking at ways blockchain technologies can facilitate the regular exchange of data, enhance the cross-organisational applicability such as national regulatory frameworks, and provide digital carbon assets with a more robust legal framework (Su et al., 2024; Swinkels, 2024). The proximity to law and the literature on economics highlights the necessity to match the technological systems with the institutional, as well as regulatory structures.

Cluster 8: Web3, IoT Integration, and Advanced Carbon Market Platforms

Cluster 8 reflects the new studies encompassing the implementation of Web3 technologies, Internet of Things devices, and real time emissions data structure within the carbon market frameworks. Some of the studies suggest sensor-based systems, which automatically create carbon credits and allow decentralized trading platforms with reactions to the facts about the environment in real time (Pan et al., 2019; Boumaiza et al., 2024; Zhou et al., 2023). According to this direction of research this suggests a move towards more data responsive and data driven mechanisms of emissions governance.

Cluster 9: Blockchain and Sustainable Development Governance

This cluster relates blockchain based carbon trading systems to the wider sustainable development systems. This has been pointed out through the research and warnings of technological determinism in the environmental governance to support the sustainability goals of the stated process through transparent emissions markets (Kim and Kim, 2020; Zheng et al., 2018). In this regard, technological design issues are interconnected with broader policy objectives in sustainability through the cluster.

Cluster 10: Climate Science Foundations and Energy Systems

Cluster 10 is based on the system modelling of energy systems and climate science, whose main foundations are the IPCC reports (IPCC, 2013). It is especially important to link it to the study of blockchain

as the issue of energy usage of the digital infrastructures becomes a pertinent one. Research in this group indicates the issue of environmental effects of energy intensive blockchain consensus mechanism (Stoll et al., 2019).

Cluster 11: Emerging Intelligent Energy and Policy Adaptive Systems

The last cluster is devoted to new trends that involve blockchain and artificial intelligence, as well as dynamic energy management systems. The solution under research that can be considered entails the approach to reinforcement learning, intelligent energy coordination systems, and policy responsive platforms that can dynamically interact with carbon markets (Yang et al., 2023). This cluster is a futuristic field of study in relation to the future of digital trust infrastructures.

4.2.2 Bibliographic Coupling

The bibliographic coupling analysis creates four clusters of research streams that are different, but interrelated to blockchain-enforced carbon markets and emissions governance. Because bibliographic coupling links studies that make references to the similarities of earlier works, such clusters represent existing relationships in the literature in terms of themes, as opposed to the existence of longstanding intellectual traditions.

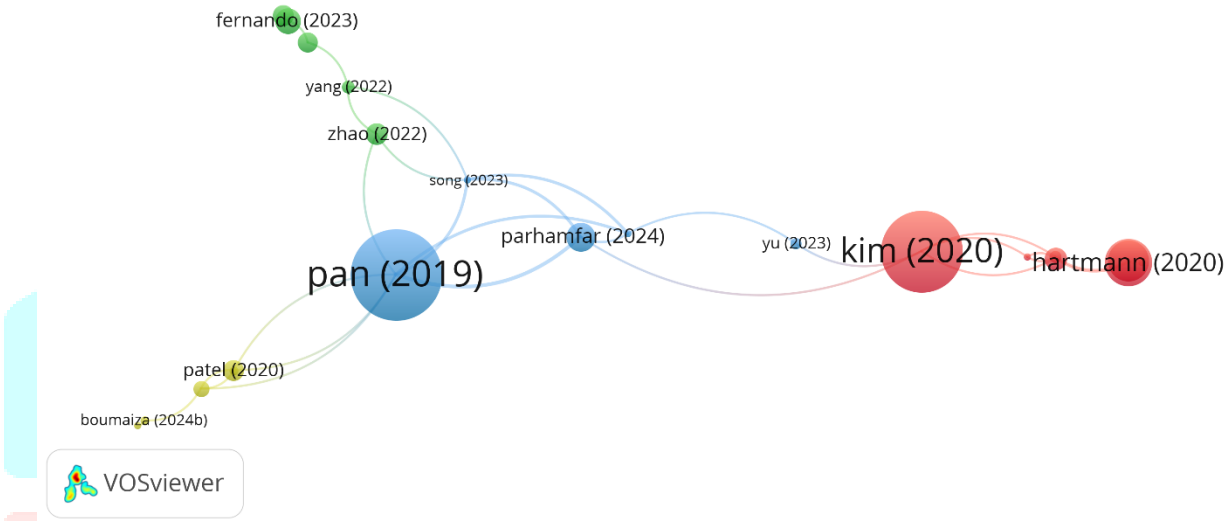

Figure 3: Bibliographic Coupling; **Source:** VOSviewer.

Cluster 1: Governance, Policy Integration, and Institutional Design of Blockchain Based Carbon Markets

Cluster 1 contains studies that analyze the possibilities of integrating the blockchain technologies in the current carbon market institutions, regulatory frameworks, and climate governance systems. Its common literature focus is on the effectiveness of the policies, governance plans, and institutional viability and is not on pure technical performance. The research in this group investigates the role of blockchain in enhancing transparency, accountability and coordination of conventional emissions trading mechanisms, including national and sectoral carbon markets (Hartmann, 2020; Richardson, 2020).

This view is furthered by some contributions which also associate the blockchain-enabled carbon markets with context wider sustainability agendas and climate finance projects such as the Sustainable Development Goals (Kim, 2020; Schloesser, 2022). Some other research works take a more critical approach to evaluating the adoption of blockchain using institutional and power-related factors and emphasize the governance issue of concern over technological optimism (Round, 2022; Chen, 2025). In general, this cluster signs the research direction that aims to enhance the current carbon governance systems instead of substituting them.

Cluster 2: Blockchain Adoption, Environmental Impact, and Organizational Use

Cluster 2 is centered around the implementation of blockchain technologies in organizational settings and also in relation to the environment. The literature on this cluster is based on technology adoption framework, environmental performance analysis and carbon footprint assessment. Empirical researches explore the adoption of blockchain technologies by organisations, especially the ones that work in manufacturing and energy intensive sectors, to facilitate the process of trading carbon credits and enhancing energy efficiency (Fernando, 2023).

Other studies within this group explore blockchain based monitoring system to monitor carbon footprints and emissions of various stakeholders including the focus on the accuracy and verification of the data (Ju, 2022). Simultaneously, a number of studies assess the environmental footprint of blockchain technologies themselves, especially, the amount of energy that they use in connection to some version of consensus (Bajra, 2024). Due to this, the literature introduces the concept of blockchain as an exciting opportunity to facilitate

the reduction of emissions, as well as a technology that has some environmental consequences and must be considered by a person.

Cluster 3: Market Mechanisms, Trading Models, and Transaction Optimization

Cluster 3 focuses on the carbon trading systems, design of transactions and efficiency of the market. In this stream of research, blockchain is mainly viewed as a technological infrastructure that facilitates a decentralized system of carbon trade. Initial research shows that with the help of blockchain, peer-to-peer carbon trading is achievable, there are fewer obstacles to market entry, and liquidity in carbon markets is enhanced (Pan, 2019).

The more recent studies work out exclusive trading models and optimization strategies such as routing schemes of high frequency carbon trade, models of urban transportation involvement, and peer-to-peer carbon exchange schemes (Song, 2023; Yu, 2023). The studies based on reviews are also present in this cluster and sum up new blockchain enabled carbons trading architectures and pinpoint technological pathways in the context of further research (Parhamfar, 2024; Abiodun, 2025).

Cluster 4: Technological Infrastructure, MRV Systems, and Consensus Sustainability

Cluster 4 is on the technological basis that needs to be in place to enable blockchain-based carbon markets. The studies under this cluster consider blockchain designs, smart contracts, Internet of Things inter-grouping, and monitoring reporting and verification infrastructures. Some of the papers suggest using blockchain based MRV models specific to the implementation sector specifics such as photovoltaic energy system and carbon auditing tools with enhanced traceability, lifecycle transparency (Luo, 2024; Boumaiza, 2024b). Other works examine economic implied incentives made possible by blockchain technologies as part of carbon trading systems such as dynamic incentive contracts and tokenized carbon markets models (Sun, 2023; Patel, 2020). Moreover, the cluster contains the studies that evaluate the environmental impact of blockchain consensus mechanisms, especially the comparisons between Proof of Work and Proof of Stake systems (Shi, 2023).

Integrative Interpretation of the Four Clusters

Altogether, the four clusters of bibliographic couplings indicate that the studies on blockchain in carbon marketplaces are functionally specialized, as opposed to highly theoretical. Studies of governance orientation, adoption research, the studies of market mechanisms, and research of infrastructure are more prone to develop in parallel with minimal concept overlap. This tendency is an indication that the development of digital climate market-based trust structures follows problem specific research trajectories instead of one supreme theoretical approach.

4.2.3 Keyword Co Occurrence Analysis

When searching with the key word co-occurrence network, three key conceptual groups in the literature on blockchain enabled carbon markets are found. These clusters were created using an algorithm and were backed with centrality measures like betweenness, closeness and PageRank parameters. All of them are markers of different conceptual areas and at the same time demonstrate how particular keywords can serve as bridges between themes of research.

Network Centrality Overview

The key word blockchain has the largest betweenness centrality and PageRank across all the network. It means that blockchain is the conceptual key that connects various thematic topics in the field of research. High centrality values are also observed in the variation of the word, with the indication that there is high centrally convergent terminology around blockchain as the fundamental organizing notion of the literature.

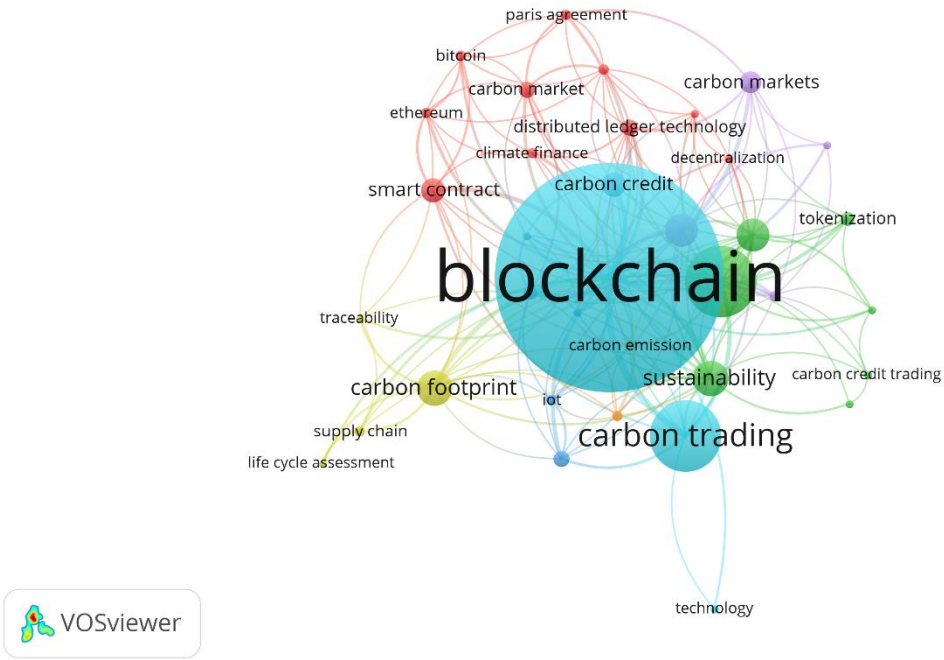

Figure 4: Key word Occurrence; **Source:** VOSviewer.

Cluster 1: Blockchain Enabled Emissions Trading and Carbon Management Systems

Cluster 1 is the biggest structurally dominant group of the keywords. It contains words referring to blockchain technologies, carbon trading systems and emissions management processes. Major centrality words are blockchain, carbon trading, carbon emissions, carbon footprint, and carbon. This cluster is the main field of operation of blockchain made carbon market research.

Cluster 2: Carbon Credits, Sustainability, and Market Transparency

Cluster 2 dwells on carbon credit and sustainability-based market structures. The key word carbon credits reveal high values of centrality in this cluster and is closely related to the term's sustainable development, transparency, carbon economy, carbon sequestration, and carbon capture and utilization. The group brings to the fore studies that connect blockchain technologies with sustainability performance and transparency on the market.

Cluster 3: Carbon Markets, Climate Change, and Distributed Ledger Contexts

Cluster 3 generalizes in terms of carbon markets and climate change. The keywords associated with it are greenhouse gases, commerce, fintech, and distributed ledger technology. This cluster frames blockchain technologies as part of more general debates of climate governance, financial innovation, and environmental policy.

Future Research Directions: Evidence Based Opportunities from Science Mapping

The overall result of the combination of co citation analysis, bibliographic coupling analysis and the Keyword co-occurrence analysis indicates a number of future directions of research. The directions appear because of structural gaps and incomplete thematic connections witnessed in the extant body of literature.

Bridging Governance Requirements and Blockchain System Design

Further studies are needed on how regulatory needs like monitoring reporting and verification standards and institutional oversight mechanisms can be directly integrated into blockchain architectures and smart contract governance structures.

Integrating Emissions Accounting, MRV, and Carbon Trading Mechanisms

Future research needs to consider how the system of emissions accounting and MRV processes can be directly incorporated into the framework of carbon credit issuance and trading instead of being different processes.

Expanding Empirical Research on Organizational Adoption

Further scientific studies are needed to explore the differences in blockchain uptake in different industries, jurisdictions, and institutional frameworks.

Reconciling Blockchain Environmental Footprint with Climate Market Objectives

Future studies should assess the environmental effects of blockchain infrastructures and discuss the trade-off between decentralization, security, and sustainability targets of the system.

Conceptual Clarification of Digital Trust

Theoretical work is still needed to understand how transparency, traceability, decentralization, and trust is applied in blockchain facilitated carbon markets.

In general, the future research agenda focuses on the concept of integration in the domains of governance, technological systems, emissions accounting practices, and sustainability goals. These guidelines offer an organized framework on how to proceed with the research on digital trust infrastructure in climate markets.

5. Future Research Agenda Based on Bibliographic Coupling

To find out the intellectual structure of the literature and to emphasize the new direction of research, the bibliographic coupling analysis was provided. The coupling map identified four important clusters of related streams of research. Studies within each cluster have similar references meaning that they are similar thematically and that they have similar topics of interest in their researches.

Cluster C1 is to integrate the digital technologies with sustainability-oriented systems. Scholarly works in this group focus on the role played by technological infrastructures and digital platforms to enhance operations efficiency and sustainability practices. Nevertheless, little empirical evidence is showing quantifiable sustainability results.

Cluster C2 brings to the fore research on technology adoption, social implications, and behavioural perspectives. This cluster of studies focuses on how user acceptance, institutional conditions, and regulatory regimes contribute to the process of the diffusion of new technologies. Future studies can explore cross cultural and cross-country variations in technology adoption patterns.

Cluster C3 targets micro energy systems and digital optimization, as well as, intelligent energy management. The studies in this bunch address the ways in which digital technologies can make energy use more efficient, increase the stability of systems, and aid in integrating renewable energy sources.

Cluster C4 looks at environmental sustainability, efficiency in the management of resources and management of the environment. This cluster of literature raises awareness of the issues that are connected to energy use and utilization of sustainable resources. Subsequent studies can involve the identification of integrated systems between technological innovation and environmental governance and policy systems.

Form these clusters, the following analysis defines critical themes, knowledge gaps, and research directions that can be followed relating to the future.

Table 2: Future Research Agenda Derived from Bibliographic Coupling Clusters

Cluster	Representative Studies	Core Research Theme	Key Knowledge Gap	Future Research Agenda
C_1 (n = 7)	Chen (2025); Zhang (2023a); Round (2022); Schloesser (2022); Hartmann (2020); Kim (2020); Richardson (2020)	Digital technologies and sustainability integration	Limited empirical evidence on the impact of digital technologies on sustainability performance	Investigate integration of AI, blockchain, and IoT in sustainable systems, conduct longitudinal empirical studies, and evaluate cross-industry digital transformation impacts
C_2 (n = 5)	Bajra (2024); Fernando (2023); Ju (2022); Yang (2022); Zhao (2022)	Technology adoption and societal impact	Limited understanding of behavioural, institutional, and regulatory drivers influencing technology adoption	Examine behavioural adoption models, cross-country comparative studies, and policy frameworks influencing digital technology diffusion
C_3 (n = 5)	Abiodun (2025); Parhamfar (2024); Song (2023); Yu (2023); Pan (2019)	Smart energy systems and digital optimization	Insufficient application of AI-based analytics in energy infrastructure management	Develop AI-driven forecasting models, apply machine learning in smart grid optimization, and study digital technologies supporting renewable energy systems

C_4 (n = 5)	Boumaiza (2024b); Luo (2024); Sun (2023); Shi (2023); Patel (2020)	Environmental sustainability and resource management	Fragmented research connecting technological innovation with environmental governance	Develop integrated sustainability frameworks, examine digital platforms enabling circular economy models, and analyze policy–technology interactions in environmental management

Source: SCOPUS database and Author's compilation

V. DISCUSSION

The results of the bibliometric performance evaluation and science mapping give some insight on how research has evolved on blockchain based digital infrastructures in climate markets. The findings indicate that in the last three years, academic attention towards the use of blockchain to support carbon accounting and emissions governance has increased significantly since 2018. This tendency is connected with the growing importance of digital technologies in solving the problems of climate governance and environmental responsibility.

The initial studies in the discipline were dominated by theoretical deliberations on the subject of blockchain technology and its possible use in the environmental systems. Indicatively, Kouhizadeh and Sarkis (2018) highlighted how blockchain systems can enhance supply chains in terms of transparency and tracking. In their work, they proposed that distributed ledger technologies can enhance the environmental reporting through the maintenance of tamper resistant records of environmental data. Likewise, Saberi et al. (2019) studied the applicability of blockchain in sustainable supply chain management and demonstrated that the technology could be used to monitor and verify environmental performance indices, as well as carbon, emissions.

The other major theme that was identified during the analysis is related to how blockchain can be effective in ensuring transparency and trust in carbon markets. Carbon markets require a trusted monitoring, reporting, and verification systems to make it credible that the reduction of emissions is done. Conventional carbon accounting systems have been seen as subject to criticism due to discontinuous systems of data, inadequate transparency, and potential of counting the same information twice. To address these issues, Andoni et al. (2019) claimed that blockchain technologies can be used to overcome them and ensure that the records of transactions remain unchanged and unverified by a specific authority.

The bibliographic and keyword co-occurring analyses also demonstrate that the research clusters regarding the carbon trading systems, climate governance framework, the decentralized carbon registries and the digital climate finance have emerged. These groups show that blockchain is gradually considered as not merely the tool but as the system of governance that can reinforce institutional divides of acting on climate.

One of the most significant issues discovered in the literature is the contribution of blockchain to the provision of digital trust infrastructures. The operation of carbon markets depends on trust since the participants of the market are to trust proper measurements of emissions and valid methods of verification. Carbon credit transactions, however, can be transparently and auditable recorded on blockchain based platforms, which makes the fraud and fraud reduction risky as well as enhancing confidence between stakeholders.

The combination of blockchain with other digital technologies, such as the Internet of Things and artificial intelligence, has also been pointed out as one of the recent research studies. To illustrate an example, the IoT sensors are capable of gathering the real time emissions data of industrial facilities whereas blockchain platforms are capable of storing and authenticating such information. This type of integration can radically change the traditional carbon accounting systems to automated and real time monitoring structures.

The results also show that the study of climate infrastructures based on blockchain is highly interdisciplinary. The contributions are based on areas like environmental economics, information systems, energy policy, and sustainability management. Such interdisciplinary nature is the indication of the complexity of climate governance issues and shows the need to integrate technological innovation with policy and institutional views.

Although the number of interested individuals in this sphere increases, it is also observed that the literature outlines various difficulties regarding the application of blockchain technologies to the climate markets. Such challenges are scalability problems, regulatory ambiguity, cross- platform interoperability, and even the environmental effects of specific blockchain consensus systems. The response to these issues will involve further cooperation between scholars, policy makers, creators of technologies, and environmental movements.

All in all, the findings indicate that blockchain technologies can be greatly used to contribute to the creation of clear and reliable climate markets. Nevertheless, this potential will be achieved based on the capacity of the stakeholders to come up with interoperable digital infrastructures and conducive regulatory systems.

VI. IMPLICATIONS

6.1 Theoretical Implications

The proposed study will make a contribution to the existing body of literature because it would provide a comprehensive science mapping of the evidence regarding the application of blockchain in carbon accounting and climate governance. Although a plethora of previous investigations have been performed either on conceptual debates or on the analysis of a particular case, the chosen research is a bibliometric one with the aim of analyzing the intellectual organization of the field.

The findings point to the fact that blockchain technologies increasingly play an important role in the wider digital trust systems in climate governance. Determining significant research groups and thematic trends in the study will facilitate the theoretical insight into the nature of distributed ledger technologies applications to promote transparency and accountability in environmental markets.

Moreover, the combination of bibliometric analysis and conceptual synthesis gives an idea of the changing connections between the research topics like carbon markets, sustainability reporting, emissions governance, and digital finance. This is because these findings help in forming interdisciplinary frameworks linking technology innovation to environmental management and concerning strategic issues in research.

6.2 Practical Implications

The results also offer a number of practical implications to policymakers, industry players, and climate governance technology developers within the arena of climate governance and carbon market emergence.

To policymakers, the findings demonstrate that blockchain based systems could be valuable to enhancing transparency and credibility in carbon accounting systems. Governments and regulatory bodies can think of implementing blockchain-based technologies to formulate safe and open registries of emissions and, thus, provide a way of minimizing the chances of data alteration and enhancing monitoring of compliance.

To businesses and other participants in the market, carbon accounting systems based on blockchain could provide them with dependable mechanisms that could monitor emissions in supply chains. Such systems will be in a position of helping organizations to show how they adhere to the environmental regulations and enhance sustainability reporting practices.

The findings also apply to those developers operating on climate technology platforms. The research indicates the areas that need technological advancement with the help of identifying the emerging areas of research and technical issues that need addressing. They are the enhancement of interoperability in blockchain platforms, energy efficient blockchain consensus algorithms and the inclusion of blockchain solutions into real time environmental monitoring technologies.

VII. LIMITATIONS

Despite the fact that this research offers valuable findings on the evolution of the research on the topic of blockchain enabled climate infrastructures, a number of limitations are to be and must be identified.

To begin with, the research is founded on the database collected in the Scopus database. Although Scopus offers a wide range of peer reviewed literature, some potentially relevant studies, which are indexed by other databases like Web of Science or Google Scholar, might have not been covered. Consequently, there is a likelihood that dataset would not be representative of the whole body of available literature.

Second, the review is limited to the publications in English language only. This can result in negation of other research published in other languages. Because climate governance and carbon markets are global topics, the contribution of non-English speaking areas as research might be able to offer more perspectives being underrepresented in the current analysis.

Third, bibliometric review is primarily based on the quantitative measures like the number of citations and relationships between key words. These indicators are helpful at determining the trends of research and the most impactful journal articles; however, they do not always capture the qualitative richness and theoretical substance of the research.

Last but not least, the field of study of blockchain and climate technologies is developing fast. New research is born all the time and this implies that the findings that are discussed here are the current status of the literature at any one time. The limitations of the present research might be overcome by involving more databases and using multilingually published documents as well as a mix of bibliometric methodologies with the qualitative uses of case-study designs in future studies.

VIII. CONCLUSION

The presented study provides a concise bibliometric performance analysis and science mapping review of the research on blockchain enabled digital infrastructures to climate markets. The analysis of scholarly sources pertaining to blockchain, carbon accounting, and emissions governance can help define the essential trends in research, prominent actors, and the emerging topic in this constantly changing arena.

The results show that blockchain technologies can enhance transparency, accountability, and trust in carbon markets through secure and tamper resistant records of the data on emission and transactions of carbon credit. Moreover, combined with other technologies of digital nature like the Internet of Things and artificial intelligence, blockchain opens new opportunities to real time emissions monitoring and automated carbon accounting systems.

The paper has also shown that the blockchain-enabled climate infrastructures research is interdisciplinary in nature. Environmental economics, information systems, energy policy and sustainability management contributions all have an important role to play in dealing with the various complexities of climate governance.

Despite the potential opportunities of blockchain technologies, there are a number of challenges that do not diminish the potential of blockchain technologies such as the problem of scale, interoperability, regulatory frameworks and the environmental sustainability of blockchain systems. It will be necessary to be innovative and collaborate as educators, governments, and economic actors to address these challenges.

Altogether, this paper can be viewed as part of the growing body of literature on digital technologies in climate governance, as it provides the systematic overview of the literature on the topics of blockchain based carbon accounting and emissions governance systems. The results are informative to scholars, stakeholders, and policy makers who are keen on coming up with clear, reliable climate market systems that would facilitate the global reduction of the climate change.

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