AI-Enabled Climate and Environmental ESG Assurance: Digital Audit Evidence, Assurance Quality and Governance A Systematic Literature Review

Furong Zhang *

School of Accounting, Beijing National Accounting Institute, Beijing, 101312 P.R. China

* Corresponding Author Email: Alice03729@163.com

Abstract. Climate and environmental ESG reports have been released at a faster rate than assurance work for these reports. Review of 19 studies published from 2020 to 2025 on AI-enabled climate and environmental ESG assurance. Assurance, audit evidence, verification, quality of assurance and governance are the subjects of this paper, not general ESG disclosures or sustainable finance. The synthesis shows that AI is most impactful when altering the evidentiary architecture of assurance; satellite observations, NLP-extracted disclosures, Scope 3 value-chain data, blockchain traces, and AI-based textual diagnostics are creating new forms of digitally processable audit evidence. According to the above, the quality of assurance is determined by the 'four Cs': characteristics, competence, content and corroboration; automation is insufficient. The paper builds an Evidence-to-Assurance-to-Governance framework and links the antecedent pressures, digital audit evidence, AI-enabled assurance procedures, assurance outcomes and governance controls. It is to provide an impetus for the discussion of general AI-for-ESG in the audit and assurance field.

Keywords: ESG assurance, climate disclosure, digital audit evidence, artificial intelligence, sustainability assurance, governance, systematic literature review.

1. Introduction

Climate and Environment Disclosures have shifted from voluntary sustainability reports to required components of corporate responsibility. Firms now report greenhouse gas (GHG) emissions, transition plans, environmental indicators and climate-risk narratives, but the growth of disclosures has not addressed the credibility problem. Gipper and others [1] have shown that ESG assurance in the United States has been expanding, but it is still divided by the type of provider, assurance scope, assurance level and assured indicators. Bu and others [2] believe that assurance can regulate greenwashing only if it serves a legitimate governance function and is not merely a symbolic endorsement.

The Guarantee Problem is inherently evidential-based. Most of the financial audit evidence is based on accounting systems and transaction data. Climate and environmental assurance generally relies on emission data, value chain information, supplier data, satellite observations, textual narratives and forward-looking risk disclosures. Gu and others [3] have shown that satellite images can be applied to support GHG verification. Khan and Teh [4] have shown that Scope 3 assurance requires data integration in the supply chain, and measurement and verification cannot be done without a digital data infrastructure.

Therefore, the first reason that AI and other digital technologies are considered necessary is that they change the concept of proof for assurance. Alotaibi and Alwathnani [5] develop a rule-based NLP artifact for Scope 2 compliance auditing. Villacampa-Porta et al. [6] Employ ClimateBERT to assess environmental disclosure quality. Chatbot [7] uses AI-based text analysis of climate disclosures and TCFD alignment. Liu and others [8] put forward a Veri-Green mechanism that integrates AI-assisted verifier matching with blockchain-based verification.

This paper reviews AI-assisted Climate and Environmental ESG Assurance. Rather than introducing applications of AI, it presents an evidence problem that requires such applications: how to integrate digital evidence into assurance, how AI-enabled processes impact assurance quality, and

what governance conditions ensure the reliability of this assurance. This paper offers a focused review sample, clarifies the concept of digital audit evidence, and develops an Evidence-to-Assurance-to-Governance framework for climate and environmental assurance.

2. Conceptual Scope and Analytical Perspectives

This review is narrower than a general AI-and-ESG review. Research in the area of climate and environmental ESG assurance, focusing on GHG emissions, environmental performance and climate-related narrative disclosures. Exclude ESG rating, sustainable investment and CSR communication studies unless they directly inform assurance, audit evidence, verification or assurance governance.

The first analysis view is audit risk and evidence. Determine if the output of AI, satellite observation, text classification and blockchain records meets the conditions of relevance, reliability and verifiability. Gu et al. [3] is a typical case that converts external environmental observations into possible audit evidence and does not treat sustainability information as mere management statements.

The second is the assurance quality and credibility. Krasodomska et al. [9] consider the provider, scope and level of assurance to determine assurance quality. Asante-Appiah and Lambert [10] have found that if they are knowledgeable about ESG, the external auditors can help the company manage ESG reputation risk. Therefore, it is unknown whether the added assurance has increased the reliability of digital evidence.

The third is governance; de Villiers and others [11] believe that AI-generated and AI-processed sustainability information will increase accountability and the risk of greenwashing. Karmańska [12] presents the conditions for applying AI in sustainability verification as explainability. Governance is thus regarded as a continuous system of supervision rather than an end result of assurance.

3. Methodology

3.1 Search Protocol And Core Search String

Based on PRISMA 2020, a systematic literature review will be conducted (Page et al. [13]). The search window is 2020-2025, and AI applications, climate disclosure regulations, and research on sustainability assurance have recently been accelerating. Searches and manual screening included Web of Science, SpringerLink, Emerald Insight, ScienceDirect, SSRN and citation searching.

The four parts of the main search string are as follows: (assurance OR audit OR attestation OR verification) AND (ESG OR sustainability OR climate OR environmental OR GHG OR emissions) AND (artificial intelligence OR AI OR machine learning OR NLP OR large language model OR foundation model OR blockchain OR satellite OR IoT OR Audit 4.0) AND (evidence OR quality OR governance OR credibility OR greenwashing). A String is required by all databases.

The query found 128 items. Remove duplicates and exclude clearly ineligible records to get 72 screened records. Forty-three reports were requested for collection, and eight could not be obtained. Thirty-five full-text reports were screened. Thematic reduction resulted in 19 studies for the final review.

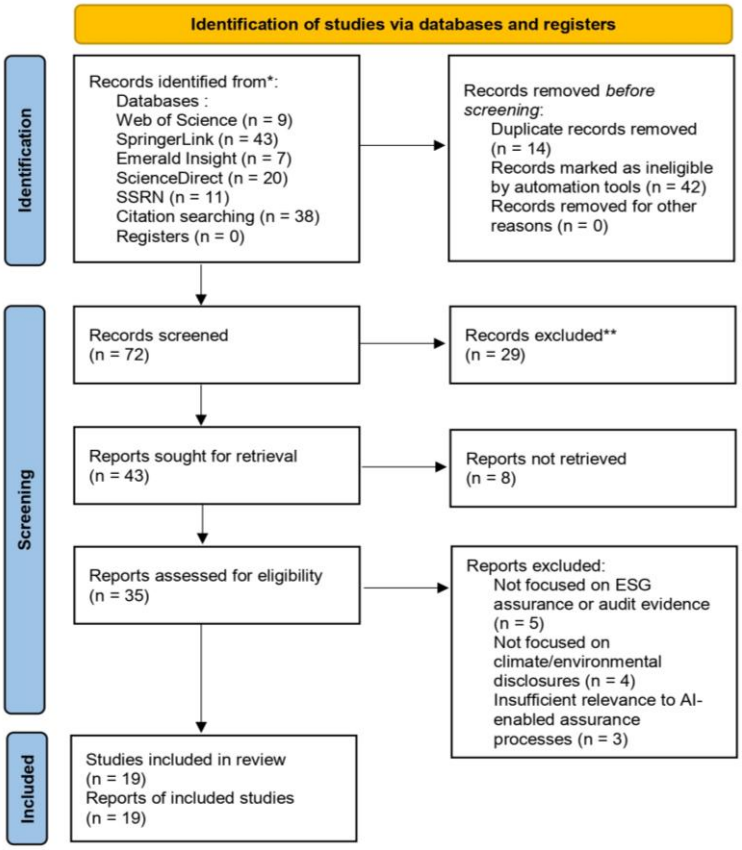


Figure 1. PRISMA 2020 flow diagram for the systematic review

3.2 Screening, Coding And Quality Appraisal

Studies were included if they dealt with climate or environmental ESG assurance, audit evidence, verification, assurance quality, audit expertise or governance mechanisms, and if AI or digital technologies had been applied to the assurance process. Studies were excluded that focused on ESG reporting, ESG investment or CSR without assurance content; those lacking a climate or environmental focus; those discussing digitalisation without assurance relevance; and those adding conceptual overlap without strengthening the final synthesis.

All included studies were coded for climate/environmental objects, assurance functions, digital mechanisms, evidence sources, research designs, governance relevance and contributions to the review. Quality assessment was subjective and thus unreliable. Assess the studies for clarity of purpose, appropriateness of design, transparency of evidence, analytical fit, and relevance to the review questions.

4. Review Sample and Core Findings

The final sample is concentrated in 2023-2025, and thus AI-enabled climate and environmental assurance is still a new area that is developing steadily. Although these studies have used different methods, they have all reached the same practical conclusion: the claims of climate and environment require external verification, digital traceability and professional governance.

Table 1. Included studies and analytical contribution

Study	Design / setting	Digital evidence or AI mechanism	Contribution
Gu et al. [3]	Proof-of-concept case	Satellite imagery for GHG	External observations as audit evidence
Li et al. [14]	Process framework	AI and continuous assurance	AI applications across assurance processes
Föhr et al. [15]	Prototype paper	Foundation models; LLMs	Foundation-model support for report auditing
Karmańska [12]	Applied model chapter	XAI; SHAP	Explainability for sustainability attestation
Alotaibi & Alwathnani [5]	Design science	NLP; Scope 2 rule checks	Transparent emissions-compliance testing
Khan & Teh [4]	Systems perspective	AI for Scope 3 data	Digital evidence for value-chain assurance
Gipper et al. [1]	Large-sample archival	ESG assurance market	Growth and heterogeneity of assurance
Krasodomska et al. [9]	European empirical study	Assurance quality	Provider, scope and level quality differences
Bu et al. [2]	Governance study	Assurance; greenwashing	Assurance as greenwashing discipline
de Villiers et al. [11]	Critical framework	GenAI; text processing	AI risks for reporting and accountability
Villacampa-Porta et al. [6]	NLP empirical study	ClimateBERT	AI assessment of disclosure quality
Haider & Nishitani [20]	Archival governance	Ownership; board governance	Governance determinants of assurance
Rao et al. [16]	Textual/panel models	LDA; SHAP; assurance	Topics, firm value and assurance moderation
Liu et al. [8]	Mechanism-design platform	AI; blockchain; VCG	Verification infrastructure for ESG reporting
Issa [17]	Archival governance	External assurance; GHG	Assurance and committees in emissions reduction
Strakova et al. [18]	Interview study	CSRD; assurance providers	Institutional preparation for mandatory assurance
Pham et al. [19]	Archival audit study	Auditor climate expertise	Expertise and climate-disclosure quality
Chabot [7]	AI textual analysis	BERT; LDA; GNTM	TCFD alignment and disclosure maturity
Asante-Appiah & Lambert [10]	Archival audit study	Auditor ESG expertise	Auditors in ESG reputation-risk management

4.1 AI Reshapes Risk Assessment And Testing

AI first impacts assurance through risk identification and testing. Alotaibi and Alwathnani [5] applied natural language processing (NLP) to extract reported Scope 2 data and provided support for rule-based compliance checks according to the GHG Protocol. Chatbot [7] has used AI to perform text analysis of the maturity and TCFD alignment of climate disclosures. Villacampa-Porta et al. [6] propose a ClimateBERT-style method for evaluating environmental disclosure quality on a large-scale reporting dataset.

4.2 Digital Audit Evidence is the Distinctive Contribution Of AI-Enabled Assurance

The strongest conceptual contribution of this school is not automation but the expansion of audit evidence. Gu and others [3] have used satellite images to provide this support and thus have

independently verified the environmental problems. Khan and Teh [4] extend the above research to Scope 3 emissions, and assurance requires web scraping, supplier information, data matching and value chain integration. Liu and others [8] have added a verification-infrastructure view by demonstrating how AI-enabled verifier matching and blockchain records can improve transparency and traceability.

Broadly interpret the meaning of digital audit evidence. External observations, machine-readable disclosures, unstructured text, supply-chain data, IoT traces and blockchain records are included. Li and others [14] are useful here because they view AI as part of a broader assurance process rather than an independent instrument; de Villiers and others [11] have also pointed out that AI-generated sustainability reports may become defective evidence if there is a lack of accountability and human oversight.

4.3 Assurance Quality Depends on Evidence, Expertise And Judgement

Assurance Quality cannot be reduced to Automation. Gipper and others [1] have explored the development of ESG assurance, but at present, there are various types of providers and different scopes and depths of assurance in the market. Krasodomska et al. [9] provide a quality-of-heterogeneity interpretation and focus on provider, scope and level as the main assurance-quality dimensions. Rao et al. [16] link report topics, firm value and assurance, and show that assurance can change how sustainability information is interpreted by the market.

Credibility effects of assurance depend on whether the assurance restricts weak disclosure. Bu and others [2] have shown that ESG assurance can be used to prevent greenwashing as a governance device. Asante-Appiah and Lambert [10] have moved the external auditor closer to the ESG risk environment and shown that auditor involvement can help manage ESG reputation risk. Therefore, the quality view of AI-enabled assurance is that digital tools can enhance the support of evidence, judgment and credibility.

4.4 Governance Determines Whether AI-Enabled Assurance is Credible

Governance is not external to AI-assisted assurance. Pham and others [19] show that auditor climate expertise is related to higher-quality climate-risk disclosure. Haider and Nishitani [20] think that ownership and board governance help explain the assurance decisions for sustainability reports. Issa [17] connects external sustainability assurance and the internal governance committee to emissions reduction. Strakova et al. [18] add an institutional dimension and show how assurance providers are preparing for the new EU sustainability assurance requirements.

AI adds to the government's governance demands by creating interpretable and accountable-of-outputs. Karmańska [12] focuses on explainability in sustainability attestations, and de Villiers et al. [11] warn that AI-generated and AI-processed reports may reproduce bias, ambiguity and greenwashing if not regulated. Governance thus refers to the whole EAG system and affects evidence design, model selection, assurance scope, etc.

5. Evidence-to-Assurance-to-Governance Framework

The EAG framework is a system for organising research that is not based on causality. Its purpose is to demonstrate that for the assurance of climate and environmental ESG information to be credible rather than just technology-driven, digital audit evidence, AI-enabled assurance procedures, assurance results and governance accountability must be aligned.

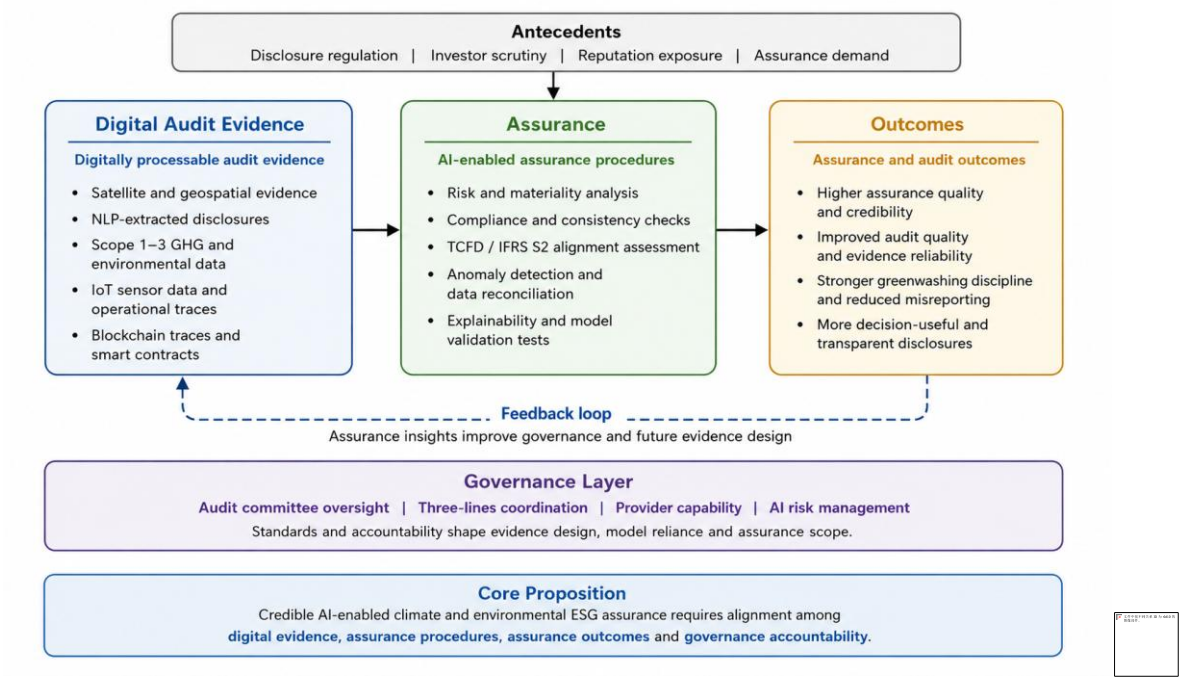


Figure 2. Evidence-to-Assurance-to-Governance framework for AI-enabled climate and environmental ESG assurance

The first idea of this system is that credible AI-assisted climate and environmental assurance requires coordinating digital evidence, assurance processes, assurance results and governance accountability. An unprotected Evidence layer is a risk to models and data. Good governance lacks an extended body of evidence. Automated assurance without explainability is becoming a new type of black-box legitimacy.

6. Conclusion and Future Research Directions

A total of 19 studies on AI-enabled climate and environmental ESG assurance have been released since 2020. Therefore, the area of study has been gradually defined as a specific assurance problem: the required evidence for climate and environmental disclosures is more external, more technical, and consequently harder to verify than traditional financial information. AI, satellite data, NLP, foundation models, blockchain and textual analysis can all be applied to this task, but they also have problems of data quality, explainability, independence and governance.

In the future, we will not only consider applying AI to ESG auditing. Specific Questions Include: When AI-generated evidence meets the audit reliability requirements, how to document and verify model output by auditors; Whether AI enhances assurance quality or only reduces costs; How audit committees and internal audit departments should oversee AI-enabled assurance. The most relevant empirical studies will be at the level of engagement, and their quality and depth are similar to other cases.

References

[1] Gipper, B., Ross, S., & Shi, S. X. (2025). ESG assurance in the United States. Review of Accounting Studies, 30(2), 1753-1803. https://doi.org/10.1007/s11142-024-09856-2

[2] Bu, M., Liu, X., Zhang, B., Hazaea, S. A., Fan, R., & Wang, Z. (2024). Governance of corporate greenwashing through ESG assurance. Systems, 12(9), 365. https://doi.org/10.3390/systems12090365

[3] Gu, Y., Dai, J., & Vasarhelyi, M. A. (2023). Audit 4.0-based ESG assurance: An example of using satellite images on GHG emissions. International Journal of Accounting Information Systems, 50, 100625. https://doi.org/10.1016/j.accinf.2023.100625

[4] Khan, T., & Teh, D. (2025). Conceptualization of artificial intelligence use for GHG Scope 3 emissions measurement, reporting, monitoring, and assurance: A critical systems perspective. Sustainability, 17(22), 10153. https://doi.org/10.3390/su172210153

[5] Alotaibi, E. M., & Alwathnani, A. M. (2025). AI-enabled ESG compliance audit for stakeholders. Sustainability, 17(21), 9513. https://doi.org/10.3390/su17219513

[6] Villacampa-Porta, J., Coronado-Vaca, M., & Garrido-Merchán, E. C. (2025). Impact of EU non-financial reporting regulation on Spanish companies' environmental disclosure: A cutting-edge natural language processing approach. Environmental Sciences Europe, 37, 29. https://doi.org/10.1186/s12302-025-01067-z

[7] Chabot, M. (2025). Textual and AI-based analysis of climate disclosures: Evidence from the European energy sector. The British Accounting Review, 101736. https://doi.org/10.1016/j.bar.2025.101736

[8] Liu, L., Ma, Z., Zhou, Y., Fan, M., & Han, M. (2024). Trust in ESG reporting: The intelligent Veri-Green solution for incentivized verification. Blockchain: Research and Applications, 5(2), 100189. https://doi.org/10.1016/j.bcra.2024.100189

[9] Krasodomska, J., Zarzycka, E., Street, D. L., & Grabowski, W. (2025). The impact of companies' trust-building efforts on sustainability reporting assurance quality: Insights from Europe. Meditari Accountancy Research, 33(7), 246-279. https://doi.org/10.1108/MEDAR-05-2024-2496

[10] Asante-Appiah, B., & Lambert, T. A. (2023). The role of the external auditor in managing environmental, social, and governance reputation risk. Review of Accounting Studies, 28(4), 2589-2641. https://doi.org/10.1007/s11142-022-09706-z

[11] de Villiers, C., Dimes, R., & Molinari, M. (2024). How will AI text generation and processing impact sustainability reporting? Critical analysis, a conceptual framework and avenues for future research. Sustainability Accounting, Management and Policy Journal, 15(1), 96-118. https://doi.org/10.1108/SAMPJ-02-2023-0097

[12] Karmańska, A. (2025). Explainable AI in the attestation of sustainability reporting. In E. W. Ziemba, W. Grzenda, & M. Ramsza (Eds.), Explainable Artificial Intelligence for Sustainable Development: Advancing Social and Economic Transformations (pp. 88-109). Routledge. https://doi.org/10.4324/9781003599227-7

[13] Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

[14] Li, N., Kim, M., Dai, J., & Vasarhelyi, M. A. (2024). Using artificial intelligence in ESG assurance. Journal of Emerging Technologies in Accounting, 21(2), 83-99. https://doi.org/10.2308/JETA-2022-054

[15] Föhr, T. L., Schreyer, M., Juppe, T. A., & Marten, K.-U. (2023). Assuring sustainable futures: Auditing sustainability reports using AI foundation models. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4502549

[16] Rao, S., Juma, N., & Srinivasan, K. (2025). Textual analysis of sustainability reports: Topics, firm value, and the moderating role of assurance. Journal of Risk and Financial Management, 18(8), 463. https://doi.org/10.3390/jrfm18080463

[17] Issa, A. (2025). Driving emissions reduction: The power of external sustainability assurance and internal governance committees. International Journal of Disclosure and Governance, 22(1), 140-154. https://doi.org/10.1057/s41310-024-00242-7

[18] Strakova, J., Traxler, A. A., Aschauer, E., Greiling, D., & Daurer, U. (2025). The institutionalisation of sustainability information assurance: Preparing for upcoming obligations in the EU. Journal of Accounting & Organizational Change, 21(7), 196-216. https://doi.org/10.1108/JAOC-02-2024-0066

[19] Pham, L., Hay, D., Miihkinen, A., Myllymäki, E.-R., Niemi, L., & Sihvonen, J. (2024). Climate risk disclosures and auditor expertise. The British Accounting Review, 101439. https://doi.org/10.1016/j.bar.2024.101439

[20] Haider, M. B., & Nishitani, K. (2022). Ownership structure, corporate governance, and assurance in sustainability reporting: Evidence from Japan. International Journal of Disclosure and Governance, 19(4), 415-433. https://doi.org/10.1057/s41310-022-00149-1