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Machine-Readable Sustainability Reporting and Assurance: A Systematic Literature Review

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Abstract

Sustainability reports are expected to be readable by software as well as people, yet structured disclosure is often treated as if it also solved underlying measurement and assurance problems. This review examines what machine-readable reporting changes, where its benefits arise, and why a tagged disclosure may still be difficult to assure. A PRISMA-informed search of the Consensus scholarly index was conducted on 7 August 2026. Five relevance-ranked searches produced 50 records; after removing duplicates and applying journal, scope, and metadata criteria, 30 peer-reviewed studies published between 2011 and 2026 were retained. The evidence was coded by digital function, accounting mechanism, research design, and reported limitation. Four findings emerge. Taxonomies and XBRL improve accessibility and can support comparison, but extensions and uneven user capabilities may weaken those gains. Reporting quality depends on upstream source systems, controls, and measurement choices rather than tagging alone. Digital tools expand the evidence available to assurance providers while creating new assurance objects, including models, interfaces, and provenance logs. Finally, interoperability remains partly institutional because ISSB, ESRS, and GRI serve different materiality purposes. The review develops an assurance-ready reporting chain and proposes research that follows sustainability facts from origin to tagged disclosure and assurance conclusion.
***Keywords**: digital reporting, ESG, machine-readable reporting, sustainability assurance, XBRL*

Abstrak

Laporan keberlanjutan semakin dituntut agar dapat dibaca oleh perangkat lunak, bukan hanya manusia. Namun, penyajian terstruktur kerap diperlakukan seolah-olah telah menyelesaikan persoalan pengukuran dan asurans. Kajian ini menelaah perubahan yang dihasilkan pelaporan terbaca mesin, sumber manfaatnya, dan alasan suatu pengungkapan bertanda digital tetap sulit diaudit. Penelusuran bergaya PRISMA dilakukan melalui indeks ilmiah Consensus pada 7 Agustus 2026. Lima pencarian menghasilkan 50 rekaman; setelah duplikasi dihapus dan kriteria jurnal, ruang lingkup, serta metadata diterapkan, 30 artikel terulas sejawat periode 2011–2026 dipertahankan. Bukti dikodekan menurut fungsi digital, mekanisme akuntansi, desain penelitian, dan keterbatasan yang dilaporkan. Hasilnya menunjukkan bahwa taksonomi dan XBRL memperluas akses dan mendukung perbandingan, tetapi ekstensi taksonomi serta ketimpangan kemampuan pengguna dapat mengurangi manfaat tersebut. Kualitas laporan tetap bergantung pada sistem sumber, pengendalian, dan pilihan pengukuran sebelum proses penandaan. Perangkat digital juga memperluas bukti asurans sekaligus menciptakan objek pemeriksaan baru, termasuk model, antarmuka, dan catatan asal-usul data. Kajian ini mengembangkan rantai pelaporan siap-asurans dan agenda riset yang menelusuri fakta keberlanjutan sejak asal data hingga pengungkapan bertanda serta kesimpulan asurans.
Kata kunci: pelaporan digital, ESG, pelaporan terbaca mesin, asurans keberlanjutan, XBRL

Introduction

A sustainability fact can now travel from an energy meter to an enterprise system, into a taxonomy, and finally into a filing that software can query. That route sounds tidy. In practice, each step may alter the meaning of the number. A meter can be misconfigured; a supplier estimate can use a different boundary; an analyst can map the amount to an overly broad taxonomy element; and a preparer can extend the taxonomy in a way that makes the disclosure technically valid but difficult to compare. The finished report remains machine-readable throughout. This is the central problem addressed in this review: digital structure improves the movement of information, but it does not itself establish that the information faithfully represents an environmental or social condition.

The distinction has become more consequential as sustainability reporting moves from voluntary documents toward regulated digital filings. The IFRS Foundation published the IFRS Sustainability Disclosure Taxonomy in 2024 to reflect IFRS S1 and IFRS S2, while EFRAG released the first ESRS XBRL taxonomy in the same year for delivery to European authorities (EFRAG, 2024; IFRS Foundation, 2024). These taxonomies are not merely new output formats. They convert disclosure requirements into data concepts, dimensions, validation relationships, and links between narrative and numerical facts. Firms consequently face a form of accounting work that joins standard interpretation, data architecture, taxonomy judgment, and internal control.

Research on XBRL supplies a useful warning against easy technological claims. Early studies associated structured financial reporting with reduced information asymmetry and improved comparability (Dhole et al., 2015; Liu et al., 2017; Yoon et al., 2011). Yet Blankespoor et al. (2014) found that the initial US mandate did not benefit all market participants evenly; more sophisticated users could exploit structured data sooner than smaller investors. Later cross-country evidence links XBRL adoption to financial reporting quality, with institutional setting shaping the strength of the association (Tawiah & Borgi, 2022). Digital accessibility, in other words, is a capability whose effects depend on taxonomy quality, implementation discipline, supporting institutions, and the user's ability to process the data.

Sustainability reporting adds further difficulty. Much of the information originates outside the general ledger. Carbon estimates rely on activity data and emission factors; workforce indicators may be distributed across jurisdictions; value-chain information may arrive through spreadsheets or questionnaires; and materiality judgments determine which facts enter the report at all. Birahim (2026) describes the problem as one of information infrastructure: when ESG data remain detached from authoritative enterprise systems, reconciliation and transaction-level verification become difficult. The tagging layer can expose this weakness, but it cannot repair it after the fact.

The assurance landscape is changing at the same time. The International Standard on Sustainability Assurance 5000 (ISSA 5000) establishes a general global standard applicable across sustainability topics and reporting frameworks (IAASB, 2024). Its arrival makes the relationship between digital reporting and assurance more than a speculative research question. Machine-readable facts can support automated validation, complete-population tests, exception analysis,

and traceable links to evidence. They also create new assurance objects: taxonomy extensions, mapping rules, application programming interfaces, calculation models, access controls, and machine-generated narrative. Bakarich et al. (2020) illustrate how blockchain may reinforce provenance, while de Villiers et al. (2024) show that generative AI can improve processing and simultaneously make plausible greenwashing cheaper to produce.

Recent reviews map digital technologies across sustainability accounting, reporting, and assurance (De Silva et al., 2025; Lodhia et al., 2025). Their broad coverage is valuable, but it leaves a narrower accounting question unresolved: where in the reporting chain does digitalization create evidential value, and where does it merely encode an unresolved judgment? Studies of XBRL, ERP, cloud systems, artificial intelligence, blockchain, and life-cycle models are often discussed as separate technologies. They are connected by a common dependence on controlled provenance and stable semantics.

This systematic literature review therefore asks three questions. First, which mechanisms connect machine-readable reporting to accessibility, comparability, and reporting quality? Second, what prevents a digitally structured sustainability disclosure from becoming assurance-ready? Third, which empirical designs can test the reporting chain rather than only its final document? The contribution is a conditional account of digital reporting. It argues that machine readability is an encoding property, whereas auditability is an outcome produced across source data, measurement, control, taxonomy, disclosure, and assurance. That argument does not diminish the importance of XBRL or digital tools. It identifies the work required for those tools to produce reliable accounting evidence.

Literature Review

Machine readability as accounting infrastructure

Machine-readable reporting changes a disclosure from a page-oriented document into a set of addressable facts. XBRL supplies standardized elements, labels, references, units, periods, entities, and dimensions so that software can identify what a reported amount is meant to represent. Inline XBRL keeps this data layer within a human-readable document. The accounting value lies in semantics rather than appearance: a tagged value can be located, compared, validated, and reused without repeated manual extraction. Enachi and Botez (2023) connect this capability to timely sustainability analysis under the European Green Deal, while Faccia et al. (2021) show how ESG concepts could be brought into a structured income-statement design.

A taxonomy, however, is not a neutral dictionary. It embodies choices about what should be represented, how concepts relate, and which distinctions matter. Malinovskaya (2023) treats the absence of an accepted sustainability taxonomy as a practical risk for preparers, auditors, analysts, developers, and regulators. The release of the ISSB and ESRS taxonomies partly addresses that gap, but it also reveals that multiple reporting architectures will coexist. Molnár, Lukács, and Tóth (2025) find limited alignment in social disclosures across ISSB S2, ESRS, and GRI. This is not simply a software mapping problem: the frameworks differ in audience, scope, and materiality logic. Interoperability must therefore preserve differences that are economically meaningful instead of

forcing superficial equivalence.

Taxonomy extensions illustrate the same tension at company level. Extensions allow a firm to represent a disclosure not captured by the base taxonomy. They can protect specificity, but excessive or unnecessary extensions replace common concepts with firm-specific ones. Comparability then declines even though every item is validly tagged. Evidence from mandatory financial-reporting environments shows both possibilities. Dhole et al. (2015) report comparability effects after the SEC mandate, while Blankespoor et al. (2014) document adverse initial market consequences consistent with uneven capabilities. The lesson for sustainability reporting is modest but important: format standardization creates an opportunity for comparison; taxonomy governance and implementation choices determine whether that opportunity is realized.

From data collection to sustainability accounting

Digital sustainability reporting starts before the report. Internet-connected devices, cloud platforms, enterprise resource planning systems, and analytical models can collect and process information at a level that conventional annual reporting rarely exposed. Vărzaru (2022) associates digital capacity across European countries with sustainability accounting and reporting, and Petcu et al. (2024) report that professional cloud users regard digital transformation, data protection, and security as connected determinants of reporting quality. Pizzi et al. (2024) place sustainable ERP systems at the center of their conceptual framework because the reliability of disclosure depends on integration with routine organizational processes.

Integration is not the same as measurement. Carbon accounting makes the difference visible. Tóth et al. (2021) find gaps in the relevance and clarity of emissions information reported by major automotive firms. Molnár, Suta, and Tóth (2024) show that life-cycle reporting needs detailed inputs across fuel and vehicle cycles and that public reports often omit data needed to validate results. Tagging can identify an emissions figure consistently, yet the figure may still combine different boundaries, assumptions, or model versions. Barker and Mayer (2025) push the issue further by separating disclosure of environmental impacts from an accounting system capable of measuring externalities. Machine-readable reporting cannot substitute for the conceptual work of deciding what is being accounted for.

This upstream perspective also changes the meaning of control. Traditional controls over a report may check authorization, arithmetic, and consistency near the end of the reporting process. Digitally connected sustainability information requires controls over sensors, supplier submissions, model parameters, master data, extraction routines, and transformation rules. Birahim's (2026) ERP-to-regulator architecture is useful because it joins ESG attributes to cost objects, assets, and subledgers before disclosure. The architecture remains conceptual, but it places auditability where it belongs: in the design of the information pipeline rather than in a final tagging exercise.

Digital assurance and its new objects

Digital reporting can improve assurance in two distinct ways. First, structured facts allow validation rules to check units, periods, calculations, and

relationships across a complete filing. Second, integrated systems can preserve links from the disclosure to transactions or operational records. Lodhia et al. (2025) describe opportunities across e-taxonomies, materiality assessment, data collection, analysis, assurance, and interactive dissemination. Bakarich et al. (2020) add blockchain-based traceability as one possible provenance mechanism. Neither mechanism makes professional judgment redundant. Automated validation can detect an inconsistent unit; it cannot decide whether management chose an appropriate organizational boundary.

Artificial intelligence sharpens the distinction between process efficiency and evidential reliability. It can extract facts, classify narrative, identify anomalies, and assist an assurer in reviewing large populations. It can also generate fluent descriptions that are detached from operational performance. De Villiers et al. (2024) identify greenwashing as a central risk of automated text production. Where preparers use models to draft or translate sustainability narrative, assurance may need to address prompt governance, source grounding, version control, and human approval. The object of assurance expands from the published statement to the system that produced it.

The literature therefore suggests a layered conception of digital assurance. The first layer concerns technical validity: whether the filing conforms to its taxonomy and calculation rules. The second concerns process reliability: whether source data, transformations, and approvals operated as designed. The third concerns measurement validity: whether the methods and assumptions represent the stated sustainability matter. The fourth concerns reporting judgment: whether material information has been selected and presented in accordance with the applicable framework. Only the first is primarily solved by machine readability. The other layers can be supported by digital evidence but still require control evaluation and professional judgment.

Research Methods

The review followed a systematic, problem-driven design suited to a heterogeneous and emerging field. PRISMA 2020 informed the reporting of identification and screening decisions (Page et al., 2021), while Snyder's (2019) guidance was used to keep the synthesis aligned with a defined conceptual problem rather than a catalogue of technologies. A statistical meta-analysis was not appropriate because the studies examined different outcomes, units of analysis, and research settings. The aim was to compare mechanisms and boundary conditions across archival, survey, case, design, review, and conceptual evidence.

Consensus was used as the academic discovery platform. The search was completed on 7 August 2026. Five queries were run: “machine-readable sustainability reporting XBRL ESG accounting”; “digital sustainability reporting assurance accounting XBRL”; “sustainability disclosure taxonomy XBRL ESRS ISSB accounting”; “digital technologies sustainability accounting reporting assurance”; and “XBRL reporting quality comparability information asymmetry accounting.” For the first four searches, publication coverage was limited to 2017–2026. The fifth extended to 2010 because the market and comparability consequences of machine-readable financial reporting predate the sustainability taxonomies. The ten highest-ranked records from each query were captured,

producing 50 records before de-duplication.

Table 1. Review protocol

Element	Operational decision
Discovery source	Consensus scholarly index; DOI and publisher metadata were checked for bibliographic identity.
Search date	7 August 2026.
Retrieval	Five queries; ten relevance-ranked records per query; 50 records before de-duplication.
Coverage	2017–2026 for sustainability/digital searches; 2010–2026 for foundational XBRL consequences.
Inclusion	Peer-reviewed journal article; English text or abstract; explicit reporting, accounting, or assurance mechanism.
Exclusion	Generic digitalization or ESG performance without a reporting mechanism; working paper; uncertain journal identity; primarily non-accounting focus.
Synthesis	Descriptive coding, primary-theme coding, and mechanism-based qualitative comparison.

Source: Author synthesis.

Ten duplicate records were removed, leaving 40 unique records for title, abstract, and metadata screening. Ten records were excluded: five discussed generic digitalization or ESG without an identifiable reporting mechanism, one was a working paper, two lacked sufficiently certain journal metadata, and two were primarily outside accounting. The final corpus contained 30 peer-reviewed journal articles. Figure 1 shows the selection sequence. Retrieval was deliberately reported as a defined relevance-ranked sample rather than described as an exhaustive census. That qualification matters because a top-ten interface rewards visible papers and may omit studies that use different vocabulary.

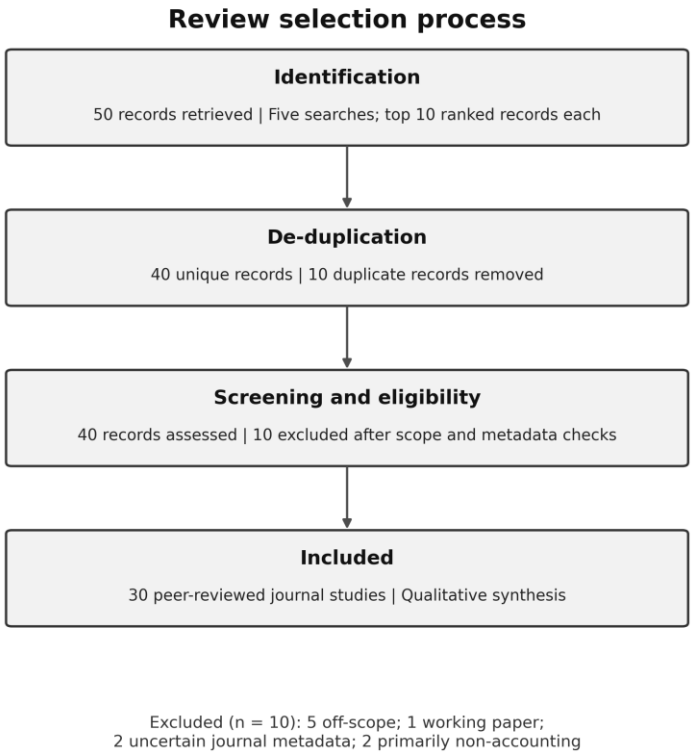


Figure 1. PRISMA-informed study selection

Source: Author synthesis.

Each included paper was coded for publication year, research design, empirical setting, digital function, accounting mechanism, reported outcome, and limitation. Research designs were consolidated into four families: quantitative archival or panel evidence; survey, interview, case, or action research; content analysis, design, or report review; and conceptual or literature synthesis. Primary themes were assigned only once to avoid inflating counts, although a study could inform several parts of the qualitative discussion. Coding then moved from technology labels to reporting mechanisms. For example, XBRL, application programming interfaces, and cloud systems were coded according to whether they changed data capture, semantic standardization, validation, dissemination, or audit evidence.

Quality appraisal asked whether the journal record was identifiable, the accounting connection was explicit, the design could support the stated conclusion, and limitations were visible. Conceptual work was retained because new taxonomies and assurance architectures remain under development, but its propositions were not treated as evidence of realized outcomes. The same caution was applied to cross-sectional perceptions. A respondent's expectation that XBRL improves transparency is relevant adoption evidence, but it does not establish that a filed sustainability fact is more accurate.

Three limitations remain. First, the review used a single relevance-ranked discovery platform and an English-language screen. Second, the corpus combines mature financial XBRL evidence with emerging sustainability applications. That choice enables learning across settings but not a claim that the effects are identical. Third, six 2026 studies were available by the search date;

several are recent or online-first and have not yet accumulated independent replication. Findings involving them are treated as directional rather than settled.

Result and Discussions

Evidence profile

The publication pattern shows a pronounced shift after 2022. The corpus contains one study in each of 2011, 2014, 2015, 2017, and 2020; two in 2021 and 2022; four in 2023; five in 2024; and six in both 2025 and the partial 2026 search year. The growth reflects the meeting of two research streams. One examines XBRL consequences in financial reporting. The other studies sustainability data, taxonomies, AI, blockchain, ERP integration, and assurance. Figure 2 presents the profile. The recent concentration also means that many sustainability-specific claims have not yet been tested across reporting cycles.

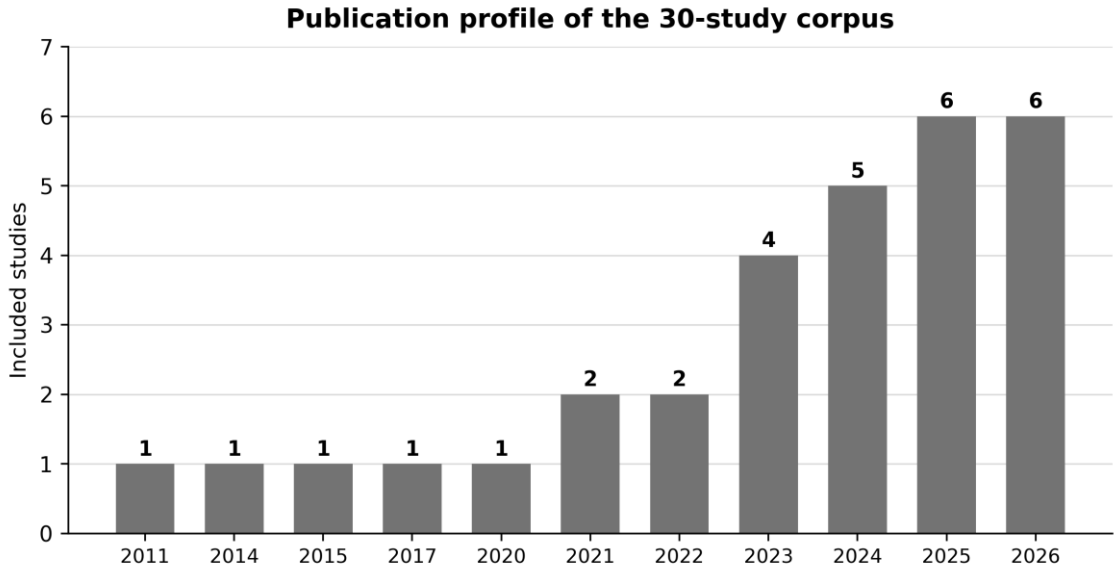


Figure 2. Included studies by publication year

Source: Author synthesis; years follow final issue metadata where available.

Table 2. Research design profile

Design family	n	Principal evidential role
Quantitative archival or panel	8	Market effects, reporting quality, cross-country digital capacity, or policy interaction
Survey, interview, case, or action research	4	Practitioner perceptions, implementation experience, and taxonomy readiness
Content analysis, design, or report review	7	Taxonomy designs, interoperability mappings, disclosure review, and use cases
Conceptual or literature synthesis	11	Frameworks, critical analyses, systematic reviews, and research agendas

Source: Author synthesis.

Table 2 reveals the field's central imbalance. Quantitative evidence is substantial enough to reject the view that digital reporting has no observable consequences, but much of it comes from financial XBRL rather than sustainability filings. The sustainability-specific literature remains weighted

toward frameworks, designs, and reviews. This is understandable during regulatory formation, but it limits claims about cost, comparability, assurance effort, and user behavior. A recurring rhetorical shortcut is to cite a technical capability automated validation, instant extraction, traceable records as if it were an achieved reporting-quality outcome. The evidence supports the capability more strongly than the outcome.

Table 3. Characteristics and contribution of the included studies

Study	Evidence form	Contribution to the review
Yoon et al. (2011)	Market study	Links XBRL adoption to changes in information asymmetry.
Blankespoor et al. (2014)	US mandate; market evidence	Shows that initial structured-data benefits can favor sophisticated users.
Dhole et al. (2015)	US mandate; archival	Examines how mandatory XBRL affects financial-reporting comparability.
Liu et al. (2017)	European archival evidence	Tests whether XBRL adoption reduces information asymmetry.
Bakarich et al. (2020)	Exploratory content analysis	Develops blockchain use cases for sustainability provenance and assurance.
Faccia et al. (2021)	Taxonomy and statement design	Proposes structured ESG disclosure linked to the income statement.
Tóth et al. (2021)	Automotive report review	Finds gaps in relevance and clarity of digitally reported carbon information.
Tawiah & Borgi (2022)	98-country panel	Associates XBRL adoption with financial-reporting quality; effects vary by setting.
Vărzaru (2022)	21-country EU analysis	Connects national digital capacity with sustainability accounting and reporting.
Alkayed et al. (2023)	Jordan; 124 respondents	Reports perceived transparency and efficiency gains from XBRL.
Enachi & Botez (2023)	Applied taxonomy example	Demonstrates XBRL's use for Green Deal sustainability information.
Malinovskaya (2023)	Comparative conceptual analysis	Identifies taxonomy, coordination, and filing risks in digital reporting.
Sabauri & Kvatashidze (2023)	Standards analysis	Discusses ISSB requirements and the need for taxonomy alignment.
Chopra et al. (2024)	Critical synthesis	Locates data accuracy, metrics, expertise, and format among ESG reporting problems.

Study	Evidence form	Contribution to the review
de Villiers et al. (2024)	Critical conceptual framework	Explains how generative AI may assist reporting and facilitate greenwashing.
Molnár et al. (2024)	Automotive LCA report review	Shows that tagged outputs need underlying model inputs to be verifiable.
Petcu et al. (2024)	Romanian professional survey	Relates cloud use, data security, and reporting digitalization to information quality.
Pizzi et al. (2024)	Fuzzy expert system	Positions sustainable ERP integration as an enabler of reporting quality.
Alharasis (2025)	Jordan; 954 observations	Finds XBRL-era improvements in the usefulness of financial information.
Barker & Mayer (2025)	Normative analysis	Separates sustainability disclosure from accounting for environmental externalities.
De Silva et al. (2025)	SLR and bibliometrics	Maps digital knowledge and integration across reporting and assurance.
Lodhia et al. (2025)	Framework and agenda	Connects technologies to the full sustainability reporting and assurance process.
Molnár et al. (2025)	Interoperability index	Finds material gaps among ISSB, ESRS, and GRI social disclosures.
Shevchuk & Shevchuk (2025)	Systemic standards review	Relates XBRL, iXBRL, and other tools to European reporting integration.
Achyar (2026)	Bank panel; staggered DiD	Finds that XBRL-enabled disclosure can strengthen climate-policy effects.
Birahim (2026)	Conceptual design synthesis	Proposes an ERP-native pipeline with provenance, validation, and exception workflows.
Kim & Yang (2026)	PRISMA thematic review	Reports uneven preparedness and sector effects under mandatory ESG regimes.
Kobiela-Pionnier & Karwowski (2026)	Interviews with XBRL experts	Finds ESRS taxonomy complexity and weak organizational readiness.
Korolyuk (2026)	Methodological synthesis	Frames digital reporting as a dynamic channel for external-user information.
Xhindole & Tarquinio (2026)	Case and action research	Finds compliance and accuracy benefits alongside standardization and greenwashing risks.

Source: Author synthesis of the 30 included journal studies.

Structured disclosure improves access, not necessarily equal access

The first research question concerns the route from machine readability to reporting quality. Three mechanisms are consistently plausible. Structured facts lower extraction costs, validation rules detect selected inconsistencies, and common concepts make cross-firm comparison easier. Yoon et al. (2011), Liu et al. (2017), and Tawiah and Borgi (2022) associate XBRL with lower information frictions or better reporting quality. Alharasis (2025) similarly reports improved usefulness after XBRL implementation in Jordan's finance industry. These findings justify investment in digital reporting infrastructure. They do not show that the format operates independently of institutions.

Two qualifications matter. The first is distributional. Blankespoor et al. (2014) find that the early SEC mandate was accompanied by outcomes consistent with sophisticated users obtaining an advantage. A machine-readable filing removes manual extraction, but users still need data, software, taxonomy knowledge, and analytical models. If those complements are unevenly distributed, the filing can increase the return to technical sophistication before it broadens access. Sustainability data may reproduce this pattern because the taxonomies are extensive, narrative tags are common, and materiality contexts are complicated.

The second qualification concerns extensions and semantics. A standard taxonomy is valuable because different firms refer to a common concept. Company-specific extensions are valuable because not every material fact fits a base concept. The two values conflict. Kobiela-Pionnier and Karwowski (2026) report that experts view the ESRS taxonomy as substantially more complex than the financial ESEF taxonomy, with many non-numeric tags and limited preparer readiness. The challenge is not merely technical training. Preparers must decide whether a disclosure is equivalent to an existing concept, how to apply dimensions, and when company specificity warrants an extension. These are accounting and governance judgments expressed through software.

Accordingly, comparability should be treated as an implemented outcome rather than a built-in feature of XBRL. A valid filing may still use inconsistent units, contexts, granularity, or extensions across firms. Automated rules can reject some errors; others require interpretation. The empirical agenda should move beyond adoption indicators and count extension rates, anchoring practices, validation exceptions, restatements, and changes in analyst processing. The relevant counterfactual is not paper versus XBRL in the abstract, but disciplined implementation versus nominal compliance.

Assurance begins upstream

The second research question asks why a tagged sustainability fact may remain difficult to assure. The literature points upstream. Sustainability information is frequently assembled through spreadsheets, surveys, and stand-alone applications rather than generated by controlled accounting systems (Birahim, 2026). This fragmentation creates reconciliation work and weakens the link between a disclosure and its source. Pizzi et al. (2024) and Petcu et al. (2024) both place system integration near the center of digital reporting quality. Their implication is straightforward: tagging should follow controlled measurement, not become a substitute for it.

Carbon reporting provides the clearest evidence. Tóth et al. (2021) and Molnár, Suta, and Tóth (2024) find that corporate disclosures often omit details needed to understand boundaries, inputs, or life-cycle calculations. A digital tag can make a reported total easy to locate while the underlying calculation remains opaque. This is a special case of a broader principle: structured data can make weak measurement easier to process without making it more faithful. Assurance work must therefore trace from the tagged fact back through transformation logic, model assumptions, and source evidence.

The same principle applies to generated narrative. A model may draft an articulate explanation of climate risk from company documents and external data. The text is processable and may even be correctly tagged. If source retrieval is incomplete, the output can omit unfavorable information or give unwarranted coherence to uncertain evidence. De Villiers et al. (2024) call attention to the resulting greenwashing risk. Assurance over such narrative may need provenance for source documents, model versions, prompts, human revisions, and approval. Traditional proofreading is not enough.

Figure 3 organizes the reporting chain. Its arrows deliberately run from source systems downward to assurance and use. This direction matters: quality defects generally propagate downstream, whereas tagging and validation provide only limited feedback upstream. A taxonomy error can be corrected at the tagging stage; an incorrectly scoped emissions inventory must return to measurement and control. The boundary conditions apply across the chain rather than to a single stage.

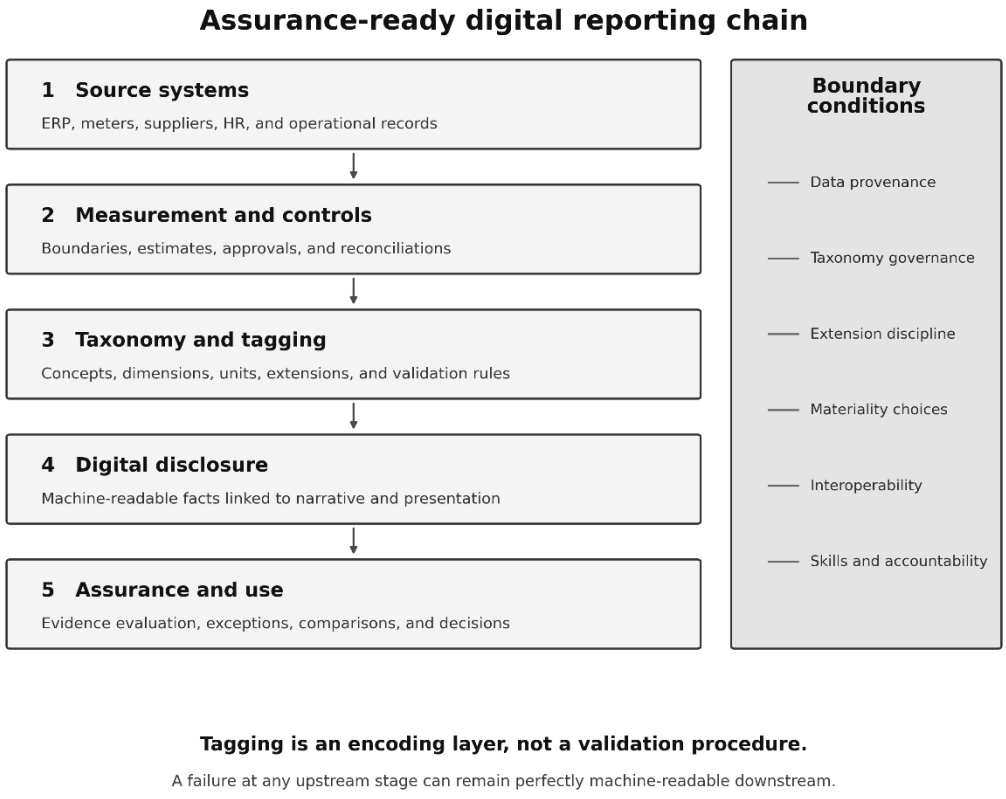


Figure 3. Assurance-ready chain for machine-readable sustainability reporting
Source: Author synthesis from the review themes.

Taxonomy interoperability is partly institutional

Interoperability is often described as a mapping task: connect one taxonomy element to another and data can flow between regimes. The reviewed evidence suggests a harder problem. ISSB standards focus on sustainability-related financial information for capital providers, ESRS incorporates double materiality, and GRI addresses organizational impacts for a wider stakeholder audience. Molnár, Lukács, and Tóth (2025) document weak connectivity across social-disclosure structures, especially where ISSB S2 is used as a point of comparison. Barker and Mayer (2025) explain why such differences cannot be dismissed as duplication: investor-oriented disclosure and accounting for external effects answer different questions.

A technically convenient one-to-one map may therefore erase meaning. For example, a workforce disclosure material because of financial risk is not automatically equivalent to one material because of impact on workers. Interoperability needs explicit metadata for materiality perspective, consolidation boundary, time horizon, unit, estimation method, and level of assurance. Where standards genuinely overlap, mapping can reduce duplicate preparation. Where their objectives differ, a bridge should preserve the difference instead of pretending that one tag satisfies both.

This finding reframes harmonization. A universal sustainability taxonomy is not necessarily the optimal endpoint. A more defensible objective is governed interoperability: stable identifiers, documented equivalences, versioned mappings, and transparent exceptions across taxonomies whose purposes remain distinct. Research can test this by tracing the same disclosure through ISSB, ESRS, and GRI filings and measuring which transformations are mechanical and which require professional judgment.

Table 4. Digital mechanisms, failure modes, and assurance implications

Digital function	Accounting value	Failure mode	Assurance implication
Automated extraction	Lower data-acquisition cost; reusable facts	Technical users capture disproportionate gains	Test user access, tools, and data transformations
Taxonomy tagging	Shared semantics and validation	Wrong concept, context, unit, or unnecessary extension	Inspect mapping controls and extension rationale
ERP and API integration	Traceability to routine records	Interfaces pass incomplete or altered source data	Test lineage, reconciliations, access, and change control
IoT and operational data	More frequent and granular evidence	Sensor error, coverage gaps, and unverified supplier data	Evaluate calibration, completeness, and exception handling

AI processing and narrative	Scalable classification, drafting, and anomaly detection	Hallucination, selective sourcing, and plausible greenwashing	Review model governance, sources, versions, and human approval
Blockchain provenance	Tamper-evident history and shared records	Immutable record of an invalid input	Separate ledger integrity from measurement validity

Source: Author synthesis.

A research agenda built around the reporting chain

The third research question concerns designs capable of testing the whole chain. Current studies often observe either the technology or the final disclosure. Both ends matter, but the accounting contribution lies in the connections between them. The next phase of research should obtain field access to source systems, mapping decisions, controls, validation logs, assurance procedures, and user behavior. It should also distinguish technical validity from reporting quality rather than using one as a proxy for the other.

Longitudinal designs are particularly valuable. ESRS and ISSB taxonomies will change, companies will revise mappings, and assurance practices will mature. A one-year comparison can confuse implementation cost with steady-state cost and novice error with permanent limitation. Studies could follow first-time filers through taxonomy updates, measure extension convergence, trace recurring validation exceptions, and compare limited with reasonable assurance engagements. Data from regulators and software platforms may permit population-level analysis if access and confidentiality are governed carefully.

Research in emerging economies also deserves a design that does not treat institutional differences as noise. Achyar (2026) finds that XBRL-enabled reporting can strengthen the effect of climate policy in banking settings across Indonesia, Malaysia, and Saudi Arabia. Birahim (2026) proposes an ERP-native route for regulatory accountability where spreadsheet reporting remains common. These studies suggest that digital infrastructure may produce larger marginal benefits where existing reporting pipelines are fragmented, but capacity, enforcement, and system maturity will condition the result. Comparative work should measure those conditions rather than infer them from country labels.

Table 5. Priority research agenda

Unresolved problem	Research question	Suitable design
Source-to-tag lineage	How often can a tagged fact be traced to controlled source records?	Field study combining process mining, control tests, and filing analysis
Taxonomy extensions	When do extensions preserve specificity or destroy comparability?	Multi-year filing panel with expert review of anchoring and extension rationale
Assurance effort	Does structured reporting reduce routine work or shift	Matched engagements using audit hours, exceptions, and evidence

	effort to systems and models?	requests
Framework interoperability	Which ISSB–ESRS–GRI mappings are mechanical and which require judgment?	Disclosure-level mapping experiment with preparers, users, and assurers
AI-generated narrative	Can provenance controls make generated sustainability text auditable?	Controlled experiment with source-grounded models and blinded assurance review
User inequality	Who captures the benefit of machine-readable sustainability information?	Investor experiment and market study separated by technical capability

Source: Author synthesis.

Taken together, the evidence does not support a simple opposition between digital optimism and skepticism. Machine-readable reporting produces real capabilities: faster extraction, programmable validation, structured comparison, and more traceable evidence. The same infrastructure can reveal weaknesses that page-based reporting concealed. A high extension rate, a validation exception, or a broken link to source data is not proof that digital reporting failed; it may be evidence that the system made an existing problem visible. The relevant question is whether organizations and assurance providers use that visibility to correct upstream processes.

The review's principal synthesis is therefore conditional. Accessibility depends on usable taxonomies and user capability. Comparability depends on disciplined concept selection, contexts, and extensions. Auditability depends on provenance, controls, and measurement documentation. Interoperability depends on preserving differences in reporting purpose. A machine-readable sustainability report becomes assurance-ready only when these conditions operate together. File format alone is neither the problem nor the solution.

Conclusion

This review examined 30 journal studies to clarify what machine-readable sustainability reporting changes and what it leaves unresolved. The literature supports three practical conclusions. First, XBRL and related infrastructures can reduce extraction costs, improve validation, and support comparison, but these gains are shaped by taxonomy governance, extensions, institutional setting, and user capability. Second, reporting quality is produced upstream. Source systems, measurement boundaries, models, reconciliations, and approvals determine whether a tagged fact is defensible. Third, digitalization changes assurance work rather than removing it. Automated checks can cover larger populations, while assurance attention moves toward data lineage, interfaces, algorithms, taxonomy decisions, and model governance.

The article contributes an assurance-ready reporting chain that separates source data, measurement and controls, taxonomy and tagging, digital disclosure, and assurance and use. The separation prevents a common category error: treating technical validity as representational faithfulness. Tagging is an encoding layer, not a validation procedure. A report can comply with a technical

specification while relying on weak estimates or incomplete source records.

For preparers, the immediate priority is to connect sustainability facts to controlled enterprise processes before selecting tags. For regulators and standard setters, governed interoperability is more credible than forced equivalence across frameworks with different materiality purposes. For assurance providers, planning should begin with the information pipeline and not with the rendered report. Future research should follow facts across that same chain, using longitudinal field evidence and disclosure-level analysis. Such work would replace broad claims about digital transformation with evidence about when machine-readable sustainability information becomes comparable, verifiable, and useful.

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