Corporate sustainability reporting and information infrastructure

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Abstract

Purpose: *Information infrastructures can enable or constrain how companies pursue their visions of sustainability reporting and help address the urgent need to understand how corporate activity affects sustainability outcomes and how socio-ecological challenges affect corporate activity. We examine the relationship between sustainability reporting information infrastructures and sustainability reporting practice.*

Design/methodology/approach: *We mobilise a sociotechnical perspective and the conception of infrastructure, the socio-technical arrangement of technical artifacts and social routines, to engage with a qualitative dataset comprised of interview and documentary evidence on the development and construction of sustainability reporting information.*

Findings: *We detail how sustainability reporting information infrastructures are used by companies and depict the difficulties faced in generating reliable sustainability data. We illustrate the challenges and measures undertaken by entities to embed automation and integration, and to enhance sustainability data quality. The findings provide insight into how infrastructures constrain and support sustainability reporting practices.*

Originality/value: *We explain how infrastructures shape sustainability reporting practices, and how infrastructures are shaped by regulatory demands and costs. Companies have developed 'uneven' infrastructures supporting legislative requirements, whilst infrastructures supporting non-legislative sustainability reporting remain underdeveloped. Consequently, infrastructures supporting specific legislation have developed along unitary pathways and are often poorly integrated with infrastructures supporting other sustainability reporting areas. Infrastructures developed around legislative requirements are not necessarily constrained by financial reporting norms and do not preclude specific sustainability reporting visions. On the contrary, due to regulation, infrastructure supporting disclosures that offer an 'inside out' perspective on sustainability reporting is often comparatively well developed.*

Keywords: sustainability reporting, information infrastructure, artifact, routine, sociomateriality

1. Introduction and supporting literature

1.1 Aims

As a growing number of companies embrace sustainability reporting[1] worldwide, the usefulness of disclosures remains problematic. Sustainability disclosures are often *not* produced and reported with the same discipline and rigour as information in statutory financial reports. Sustainability data and reporting formats are based on differing frameworks, often chosen at the companies' discretion

[1] Following Rowbottom (2023), we use "sustainability reporting" to refer to both reporting that focuses on how corporate activity affects sustainable, socio-ecological development, and reporting that considers how moves to address sustainable, socio-ecological development affect corporate performance. We therefore intend to capture practices commonly described as 'social and environmental reporting', 'non-financial reporting', 'sustainability-related financial disclosure' and 'ESG reporting'.

based on entity-specific circumstances, leading to selective and inconsistent disclosures (Accountancy Europe, 2019; Bebbington *et al.*, 2014; O'Dwyer, 2003; Parker, 2005; Soderstrom *et al.*, 2020). Whilst accurate and comparable sustainability data is increasingly required, its reliability and transparency are widely criticised (Boiral *et al.*, 2021; Cho *et al.*, 2015; Soderstrom *et al.*, 2020; WBCSD, 2019). Consequently, there is a disconnect between the information reported in sustainability reports and the sustainability challenges that companies actually face (Boiral *et al.*, 2019; Talbot and Boiral, 2015).

Extant literature has sought to explain these issues by predominantly focusing on factors external to companies (e.g., sustainability disclosure regulation and reporting frameworks, standards, stakeholder relations and norms) and ways by which such factors can affect sustainability reporting (Adams *et al.*, 2020; Bebbington and Thomson, 2013; Dillard and Pullman, 2017; Gond *et al.*, 2012; Parker, 2011; Rowbottom and Locke, 2016; Schaltegger and Burritt, 2018; Spence and Rinaldi, 2014; Tregidga *et al.*, 2012). Meanwhile scant attention has been paid to understanding the role of the company's internal context on sustainability reporting that may shape what can and cannot be reported regardless of motivations and adherence to specific standards. Specifically, the intra-organisational dynamics, mechanisms and approaches are largely considered as a 'black box' and remain comparatively unexplored (Gond *et al.*, 2012; Järvinen *et al.*, 2022; McNally *et al.*, 2017; McNally and Maroun, 2018; Senn and Giordano-Spring, 2020). We therefore aim to examine this internal context through which firms generate sustainability reporting data, and explore how this internal context can shape what type of sustainability reporting is undertaken and the quality of data disclosed.[2] In the subsection below, we introduce how we conceptualise the internal context in which sustainability data are generated and offer a detailed motivation for our specific research questions.

1.2 Motivation and research questions

In considering a company's internal context and how this may affect sustainability reporting practices, we draw on the concept of information infrastructure. This represents the socio-technical arrangement of technical artifacts such as software applications and data repositories, alongside social routines or processes (Ciborra *et al.*, 2000; Leonardi, 2011) which are collectively intended to facilitate sustainability reporting (Dillard *et al.*, 2016; Gond *et al.*, 2012; Kaspersen and Johansen, 2016; Milne and Grubnic, 2011; Vigneau *et al.*, 2015). Supporting the critical role of reporting information infrastructure, Kaspersen and Johansen (2016) observe that the "external report is a product of the ambitions, conflicts, and technical possibilities for recognizing, recording and reporting data that emerge from internal systems and processes" (p. 732). Information infrastructure can therefore affect what type of sustainability reporting is undertaken and the quality of disclosures reported in different ways (Bebbington and Thomson, 2013; Parker, 2011; Spence and Rinaldi, 2014; Watts, 2018).

Firstly, the ability to provide specific sustainability disclosures depends on the existing infrastructural capacity to reliably capture specific forms of sustainability data. However, the extent to which data are available is dependent on existing supporting artifacts such as information systems and software which may support or restrict certain types of data. For example, established, legacy information infrastructures are generally setup to capture reliable *financial* data, but struggle to deal with sustainability data from different sources both inside and outside the corporate boundary. Existing infrastructure may consequentially privilege the disclosure of aspects of

[2] We broadly refer to data quality as indicating the usefulness of information for its intended purpose (Wang and Strong, 1996; Shanks and Corbitt, 1999).

corporate activity for which data are available rather than data perceived to discharge accountability, and offer insights on the relation between corporate activity, society and the environment (Brown, 2009; Deegan, 2013).

Additionally, different standards require different types of information and current global standardisation initiatives have sought to distinguish different forms of sustainability reporting (Rowbottom, 2023). ISSB standards, described as guiding 'sustainability-related financial disclosures', focus only on those socio-environmental issues perceived by management to materially affect enterprise or firm value (CDP *et al.*, 2020b; IFRSF, 2020; IFRSF, 2021). This vision of reporting, bounded by what the European Commission (2019a) codified as 'outside in' or financial materiality, requires infrastructure that supports the collection of novel data but conforms more closely to traditional reporting processes in terms of reporting boundaries and financial materiality (see e.g., IFRS S1 (ISSB, 2023)). Conversely, standards developed by the EU and GRI offer a different vision of sustainability reporting that also considers how corporate activity affects society and the environment thereby offering an 'inside out' perspective on sustainability based on impact materiality in addition to the 'outside in' perspective based on financial materiality (so called 'double materiality' reporting) (European Commission, 2019a; Rowbottom, 2023). Sustainability reporting that employs this 'inside out' perspective thereby presents different challenges for infrastructure as data requirements extend traditional reporting processes and reporting boundaries that are based on financial control to consider the sourcing, use and disposal of materials, impact on communities and the welfare of labour employed across the entire supply chain. Whilst external factors play a role in the companies' endeavours to engage with sustainability reporting, such engagement may be enabled or constrained by the manner and extent to which established information infrastructure allows them to follow specific visions of sustainability reporting.

Secondly, the capacity to undertake sustainability reporting also depends on the availability of robust and reliable artifacts including information systems, measurement processes, and metrics which, collectively, facilitate data management and provide a basis for standardising sustainability disclosures. However, lack of mature artifacts is widely seen as a key reason constraining sustainability reporting and consequentially limiting the capacity of companies to provide particular forms of sustainability disclosures (KPMG, 2012; SustainAbility, 2019; WBCSD, 2018b; WBCSD, 2019). As a result, sustainability data quality remains a source of concern. Regulatory bodies note that "the use of proxies and assumptions where data gaps and methodological challenges are severe could lead to potentially misleading, inconsistent and inaccurate disclosures" (FCA, 2021, p. 8). In relation to key sustainability measures such as carbon emissions, Busch *et al.* (2023) note the need for "more research that advances a discussion regarding the availability, accuracy, accountability, honesty, integrity, deceptiveness, prudence, relevance and 'investability' of self-reported and/or third party curated GHG emissions data" (p. 897).

Thirdly, many companies adopting sustainability reporting either lack or have limited capacity enabling them to integrate financial and non-financial data systems (Capitals Coalition, 2020) and overcome barriers pertaining to the use of a common unit of analysis (e.g., through monetisation) (IIRC, 2019). However, integrating financial and non-financial information can improve understanding of how a company's pursuit of financial outcomes might be related to sustainable development (Deegan, 2013).

As information infrastructure is active and dynamic, it can both shape sustainability reporting practice but also be shaped by it (Power, 2015; Power, 2019; Watts, 2018). Whilst infrastructure can affect what type of sustainability reporting is undertaken and the quality of disclosures produced, companies also use prevalent sustainability reporting legislation, standards and norms to develop specific aspects of infrastructure.

A key reason why companies struggle with sustainability reporting is related to the challenges in constructing new information infrastructure or adapting traditional, legacy information infrastructure to account for sustainable development considerations (Kaspersen and Johansen, 2016). However, the mutual shaping of information infrastructures and sustainability reporting practice is seldom articulated. Accordingly, we pose the following research questions: (i) *what sustainability reporting information infrastructure is employed in practice?,* (ii) *what is the nature of the interaction between sustainability reporting information infrastructure and sustainability reporting practices, and what are the key implications?,* and iii) *how are companies seeking to develop sustainability reporting information infrastructure?*

To address these exploratory questions, we collect qualitative evidence from 30 interviewees involved in the development and use of information infrastructures for sustainability reporting alongside documentary evidence, sourced from software and technical reports from practitioners, professional bodies and standardisers. We engage with the empirics by combining a sociotechnical perspective based on the work of Pickering (1995) and the infrastructure conception of Leonardi (2011). Specifically, we use empirically observable arrangements of technical and social forms of agency, namely, technical artifacts and routines, to explore the interactions between information infrastructures and sustainability reporting practice. This analysis allows us to consider how sustainability reporting information infrastructure can afford and constrain different visions of sustainability reporting practice.

In doing so, the paper contributes by offering a nuanced account of the challenges firms face in gathering different forms of sustainability data across corporate activity through direct measurement, derivation and estimation; processing, classifying and commensurating data; and reporting in accordance with legislation and specific standards. The results show how companies have developed 'uneven' information infrastructures with mature artifacts and routines supporting legislative requirements, whilst infrastructures supporting non-legislative sustainability reporting remain comparatively underdeveloped. Consequently, infrastructures supporting specific legislation relating to carbon emissions or health and safety have developed along unitary pathways and are often poorly integrated with infrastructures supporting other sustainability reporting areas such as water usage. The paper also finds that information infrastructures are not necessarily constrained by financial reporting norms and are not restricted to only capturing data on those socio-ecological issues that are deemed to materially affect future cash flows, accordant with the 'outside-in' financial materiality perspective required by ISSB standards. On the contrary, given the influence of legislative requirements, information infrastructure supporting 'inside out' sustainability reporting is often comparatively well developed.

The paper is structured as follows. First, we detail the theoretical underpinning of the study. We then explain the methods of data collection and analysis before presenting the findings. The concluding discussion interprets the findings, explains the links with the literature and details key implications for theory and practice.

2. Theoretical underpinning

The urgent need to improve understanding of the interactions between corporate activity and socio-ecological challenges such as climate change, environmental degradation, declining biodiversity, depletion of raw materials and human rights abuses calls for significant organisational change. Reporting information infrastructures constitute a key internal organisational factor that can facilitate or inhibit this change. In this section, we discuss the theoretical underpinning of the information infrastructure conceptualisation adopted in this study.

Taking Pickering's (1993) sociotechnical perspective, we first provide an ontological framing of information infrastructure as an emergent sociotechnical assemblage, a product of the interplay between the human and technical agencies of heterogenous actors such as people, information systems, software and processes (section 2.1). To operationalise this ontological depiction of infrastructure and facilitate analytical execution, we draw on Leonardi's (2011) conceptualisation of information infrastructure as an arrangement of artifacts and routines, the empirically observable and traceable manifestations of technical and human agencies (section 2.2). We then discuss the theory of affordances to explain how and why information infrastructures may be flexible, dynamic and active and how their reciprocal, two-way relationship with sustainability reporting practice can shape sustainability reporting outcomes and more widely instigate organisational change (section 2.3) (Bowker *et al.*, 1996; Power, 2015; Power, 2019; Troshani *et al.*, 2022).

2.1 Infrastructure as a sociotechnical construct

Existing literature has looked at the nature of the relationship between the social and the technical and their respective roles in explaining social and organisational change. Central to this research is the nature of agency, the "capacity for action" (Giddens, 1984), and the manner in which it instigates change when exercised by human actors together with nonhuman, technical artifacts such as information systems and software.

Considering agency enables us to consider how both humans and technical actors perform collectively. Viewed in this way, the phenomenological distinction between human and technical agency is *intentionality* (Pickering, 1995). Human agency is "the ability to form and realize one's goals" (Leonardi, 2011, p. 147). When discussing the rationale of human intentionality, Pickering (1995) argues that human agents "construct goals that refer to presently nonexistent future states and then seek to bring them about" (p.18), where the "future states" are based on "imaginatively transformed versions" (p. 19) of the present states. Technical agency refers to "the capacity of nonhuman entities to act on their own, apart from human intervention" (Leonardi, 2011, p. 148). Accordingly, human agents take a "passive role" after engaging technical agency, observing it whilst "at work" (Pickering, 1995, pp. 51-52), and "free to perform" (Pickering, 1995, p. 79), until it produces outcomes which they subsequently "take … or leave …" (Pickering, 1995, p. 52).

The equivalence advocated for human and technical agencies is thus semiotic–though both are capacities for action, they do not constitute each other in precisely the same way. While intimately implicated in the sociotechnical assemblages in which they are entangled, human actors have particular accountabilities (Pickering, 1993; Pickering, 1995; Suchman, 2007). As a consequence, the performative capacity of technical agency is "enveloped by human practices (Pickering, 1995 p. 16) … the trajectory of [its] emergence … is bound up with that of human agency" (Pickering, 1995 p. 53).

2.2 The building blocks of infrastructure: artifacts and routines

Pickering's ontological depiction of infrastructure as a product of the interaction of human and technical agencies can be difficult to operationalise in practical research execution without the means of identifying the forms in which the agencies can manifest. Following Latour (2005), Leonardi (2011) argues that technical and human agencies become observable and traceable via artifacts and routines, respectively. Artifacts and routines are the 'figurations' or mediums with explicit form or shape that are "doing the acting" (Latour, 2005, p. 53), and together form infrastructure (Leonardi, 2011).

An artifact is an enduring, structured arrangement of constituent parts created by humans to achieve goals (Faulkner and Runde, 2019; Leonardi, 2013). As well as physical artifacts, Faulkner and Runde (2019) recognise syntactic objects as artifacts without a physical presence such as software applications, rules and policies concerning the inputting, consolidation and verification of sustainability reporting data. Artifacts provide capabilities that humans do not possess (Leonardi, 2010; Pickering, 1995). For example, when constructing artifacts such as software applications, human developers seek to capture the technical agency of the computer system's components to access capabilities for data storage, analysis and reporting.

Routines are "repetitive, recognizable patterns of interdependent actions, carried out by multiple actors" (Feldman and Pentland, 2003, p. 96) that support artifact use. As structured actions, routines are created to "set the … [artifacts] in motion and to channel and exploit their power" (Pickering, 1995, p. 16). For example, corporate reporting includes routines that leverage authentication technology such as digital signatures to ensure that transactions are authorised, whilst automated or manual routines leverage accounting systems to record transaction data in repositories, after the transactions are classified based on accounting standards.

Although routines have been described as structured, fixed actions facilitating consistent and predictable outcomes, routine scholars have challenged routine stability by arguing that routines can also be a source of organisational change (Feldman and Pentland, 2003; Pentland and Feldman, 2007). This is based on the idea that routines can be performed by "specific people, at specific times, in specific places" (Feldman and Pentland, 2003, p. 95), who have discretion and choice to interpret, modify, and ignore or reject routines (D'Adderio, 2008; Feldman and Pentland, 2003; Pentland *et al.*, 2010). Although routine performance is intended to comply with rules and expectations, the particular courses of action humans choose are always, to some extent, novel even in highly constrained situations. Humans introduce variations and "interpret their actions in order to make sense of what they are doing and, though their choices of how to proceed appear automatic or mindless at times, there is always the possibility of resisting expectations and doing otherwise" (Feldman and Pentland, 2003, p. 102).

In ways similar to artifacts, routines can also both enable or constrain human agents to produce outcomes that range from apparent stability to significant organisational change (D'Adderio, 2008; Feldman and Pentland, 2003; Pentland *et al.*, 2010). Routines and artifacts are created and used together. For example, routines are often mediated by technical artifacts. Equally, artifacts can only perform (i.e., have effects) if incorporated in routines (Leonardi, 2011; Pentland and Feldman, 2007). Both routines and artifacts are flexible and therefore change overtime as they are developed or used in infrastructure (Leonardi, 2011; Pentland and Feldman, 2007).

2.3 Infrastructural capacity

After explaining how information infrastructure is conceived and operationalised, we move on to consider how it acts. Leonardi uses the theory of affordances to explain 'action possibilities' in the built environment of humans and their artifacts (Gibson, 1986). Accordingly, affordances are the different possibilities for action that a user perceives when they encounter a particular artifact. As Leonardi (2011, p. 153) explains, "people do not interact with an object prior to or without perceiving what the object is good for." There are two critical aspects to this assertion. First, while an artifact's technical properties (e.g., an information system) may enable various functionalities, what a user perceives when confronting the artifact is generally not the properties themselves but the kind of action that the artifact supports in a given situation. Second, affordances are specific to the particular ways in which individuals perceive an artifact in relation to their action-oriented goals and the particular contexts in which they are located. Thus, the opportunities for action associated with a particular artifact are as diverse as the users' needs and goals. Consequently, while some users may perceive that an artifact affords them certain possibilities for action, others may perceive the same artifact as constraining the possibility of achieving their goals (Leonardi, 2011).

Leonardi (2011) proposes that as people engage with infrastructure, the perceived affordances and constraints influence how they use the human and technical agencies associated with it. For instance, the perceived affordances of an artifact may lead users to identify new goals that could be achieved through the technical agency of the artifact. In sustainability reporting, artifacts may enable firms to consider new possibilities of how they can collect data on their socio-ecological impacts accordant with an 'inside out' impact materiality perspective. However, achieving these new goals is likely to necessitate the exercise of their human agency to change the performance of existing routines or create new ones (Leonardi, 2011). Conversely, in confronting a technical artifact that they perceive constrains their ability to achieve their current goal, users may redesign or reconfigure the technical features of the artifact so that it does new things–giving it new technical agency. "The attempt to make human constructs amenable to computers, when we quantify the qualitative, discretize the continuous, or formalize the informal" can both enable some possibilities and constrain others (Friedman and Nissenbaum, 1996, p. 335). Consistent with Leonardi (2011), we argue that artifacts and routines are created or revised when existing infrastructure constrains human actors from achieving their goals.

In our context, there is limited understanding of how corporate activity affects sustainability outcomes and how socio-ecological challenges affect corporate activity. Reporting information infrastructure can be instrumental to help improve current understanding of these interactions (Kaspersen and Johansen, 2016; Watts, 2018). We conceptualise sustainability reporting information infrastructure as an emergent socio-technical arrangement (Pickering, 1995) that *both shapes and is shaped by sustainability reporting practices*. The capacity of how companies engage in sustainability reporting is thus shaped by these interactions. In this study, we collect data to examine these interactions, as described in the next section.

3. Data collection and analysis

We seek to explain how and why information infrastructures develop as a consequence of the interaction with sustainability reporting practice. Accordant with our research questions, theoretical underpinning and the emergent and dynamic nature of the field, we seek insights into sustainability reporting practice and information infrastructure.

Aligned with these aims, we adopt an interpretive research approach and collect qualitative evidence from companies that have adapted or are adapting their sustainability reporting information infrastructures for three key reasons.

Firstly, this approach is suitable given that sustainability reporting is in a process of rapid change as more companies are required or expected to expand the range of information being collected and disclosed accordant with existing and emergent standards (ISSB/TCFD, ESRS/GRI, TNFD) and current and proposed legislation (e.g., relating to climate change or modern slavery) that has differing implications for supporting infrastructure. These changes to sustainability reporting expectations are likely to require complex adaptations to existing information infrastructure (KPMG, 2017b). Traditional, legacy reporting information infrastructures are designed around principles that uphold the primacy of financial information for shareholders. These infrastructures *were not* designed to cater for data concerning sustainability issues such as human rights and climate change (Dillard *et al.*, 2016). Consequentially, evidence on the infrastructure in place given changing sustainability reporting expectations is likely to be rich in revealing common patterns, problems and solutions. Secondly, a qualitative approach is a consequence of and consistent with the exploratory nature of our research questions that require fundamentally qualitative accounts of the interactions between sustainability reporting information infrastructure and sustainability reporting practices. Thirdly, an interpretive, qualitative approach is consistent with the theoretical underpinning adopted in this project. Infrastructural building blocks, namely, artifacts and routines, are empirically observable and traceable arrangements that are best documented qualitatively (Latour, 2005; Pentland and Feldman, 2008). To pursue our approach, we collect an empirical dataset consisting of interview data alongside documentary evidence such as technical reports, software documentation, and white papers.

Interviews offer flexibility and provide rich insights and opportunities for exploring, identifying and understanding viewpoints pertaining to change processes, perceptions and influences (Miles and Huberman, 1994; Myers and Newman, 2007). Interviews allow control over question sequencing, clarification of responses and supplementary information (Myers and Newman, 2007; Walsham, 1995). An interview protocol was developed focusing on topics including the mutual impacts of information infrastructure and sustainability reporting practice, challenges surrounding the collection, processing, and reporting of sustainability data and supporting artifacts and routines, and the relations between different aspects of information infrastructure.[3]

Initial interviewees were identified purposively and then extended via snowball sampling from interviewee referrals (Myers and Newman, 2007; Walsham, 1995). We targeted interviewees in large international companies which were either headquartered or had operations in Australia that were significantly involved in implementing, managing or using information infrastructures, and financial and non-financial, sustainability reporting data. These multinationals were subject to significant sustainability concerns and a range of changing sustainability reporting expectations deriving from Australian legislation, legal requirements in the countries they operate, plus emergent and existing voluntary standards. At the end of each interview, interviewees were sufficiently familiar with the research aims to be able to refer investigators to other field experts. Interviewees were deliberately asked for referrals to more than one expert, ideally someone they had rarely or never met, to reduce chances of snowball samples being locked into the mindset of one network. This approach allowed us to obtain multiple perspectives and data sources to ensure depth and breadth in the dataset, but also to ensure evidence triangulation.

[3] Ethics approval was secured from the University with which one of the co-authors is affiliated.

A total of 29 interviews were conducted with 30 interviewees across 22 different companies operating in 8 industries.[4] The interviewees typically held roles such as CIOs, sustainability reporting managers, project managers, software developers, business analysts, auditors and sustainability reporting consultants. With the exception of one interviewee,[5] all other interviewees held at least a bachelor's degree; 10 interviewees held at least a postgraduate degree, including 2 who held doctorates. On average, interviewees had 17 years of working experience at the time of the interviews; the least and most experienced interviewees had 2 and 35 years of experience, respectively.

Interviews took place between March-November 2019 and ranged from 29 to 85 minutes, resulting in over 1,332 minutes of data that were recorded, transcribed and analysed. To maintain anonymity, Table 1 lists interviewee identifiers and the industry of their organisations.

Table 1. Interviewees

Interviewee identifier	**Industry**	**Number of interviewees**	**Number of interviews**	**Number of companies**
Interviewee#1-3	Mining	3	3	2
Interviewee#4-5	Manufacturing	2	2	2
Interviewee#6-10	Construction	5	5	3
Interviewee#11-13	Retail trade	3	1	1
Interviewee#14-16	Transport, postal and warehousing	3	3	3
Interviewee#17-20	Financial and insurance services	4	4	3
Interviewee#21-28	Professional, scientific and technical services	8	9	6
Interviewee#29-30	Other services – Civic, professional and other interest group services	2	2	2
Total		**30**	**29**	**22**

The diverse, rich textual data collected were analysed interpretatively. The first stage of the interview analysis involved listening to the audio recordings, examining interview notes and reading transcriptions. We then undertook higher-level, holistic first cycle coding of both interview data and relevant documentary sources based on descriptions, events and actions identified in the dataset (Saldaña, 2016). To draw meaning and interpretation, analytic memos were recorded and data were read multiple times to target higher-order generalisations by shifting between the general and the specific (Myers and Newman, 2007). In the next stage of the analysis, themes were identified and incrementally developed by condensing, clustering, and conceptually grouping identified patterns (Myers and Newman, 2007). We compared, contrasted, analysed relations, and triangulated identified patterns against data obtained from both interviewees and documentary sources. In the final stage, findings were analysed and structured iteratively until we could develop a thorough and coherent understanding of the phenomena represented in the dataset, whilst ensuring we could maintain a logical chain of evidence (Yin, 2009).

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[4] We classified the companies with which the interviewees are associated using the Australian and New Zealand Standard Industry Classification (ANZSIC). We deliberately use the highest level of industry classification to reduce possible risk of compromising anonymity of interviewees and companies.

[5] One interviewee declined to provide personal information.

4. Analysis and findings

In the following subsections, we discuss the relation between reporting information infrastructure and sustainability reporting practice using our dataset. Addressing the first research question, subsection 4.1 examines what sustainability reporting information infrastructure is employed by practitioners, and identifies key issues surrounding the measurement, collection and processing of sustainability data. Subsection 4.2 considers what drives sustainability reporting infrastructure, which alongside content from subsection 4.1, addresses the second research question concerning the interaction between information infrastructure and sustainability reporting practices, and emergent implications. Addressing the third research question concerning how companies are seeking to develop sustainability reporting information infrastructure, subsection 4.3 explores the extent to which sustainability reporting systems are being integrated whilst subsection 4.4 examines how firms are attempting to improve data quality.

4.1 Artifacts and routines

Our evidence suggests that companies have developed a range of artifacts and routines to support sustainability reporting. Data collection and preparation routines use artifacts such as dedicated data capture tools, data entry forms and spreadsheets. Data analysis is carried out using templates, dashboards and dedicated systems. Reporting routines are used to produce sustainability disclosures which are presented to users in a range of artifacts including project-based summaries, dedicated websites and sustainability reports and in specific sections of the annual reports. Dedicated control routines have also been established for auditing and assuring data quality and those methods used to produce disclosures.

Infrastructure as socio-technical entanglement In describing the reporting information infrastructure being used, the accounts of practitioners indicated how infrastructure was constituted through the socio-technical entanglement of information systems, analysis tools and social routines performed by employees. In the quote below, we illustrate how the agency of technical artifacts such as SAP and Power BI are bounded by human agency:

> *For us it's SAP. There is GBs and GBs and GBs of data in there. We've got goals around packaging. All packaging will be 100% recyclable and over the range of our skews greater than 50% of the resource used will be of recycled content. For example, from a bottle perspective at the moment you can go up to 100% recycled content in a PET [polyethylene terephthalate] bottle that's up to a certain size. In HDPE [high density polyethylene] which is your 2-3 litre milk bottle, at the moment you can only get to about 50%. Across the range at least half of the resin that we use needs to be from a recycled content. I am working on a Power BI dashboard for that at the moment. What's been the difficult aspect is you've got to have someone who understands planning because the planning is we want one cap, we want one bottle, we want 'x' mls of milk, we want 'x' grams of sugar, 'x' grams of cocoa powder etc. You've got to find the person who has that understanding of planning and understanding how SAP works to be able to make sure that if I am going to set up a dashboard that it's going to be as accurate as it possibly can be to reflect the goal–the percentage recycled content. (Interviewee#4)*

Practitioners also highlighted how existing infrastructural capacity shaped what data were available and how this did not necessarily equate with what data might be required. In the quote below, the interviewee highlights how data supporting a new sustainability metric is based on an interaction between what is wanted and the quality of data available.

> *It's working with the data owners and the people who have visibility of it to identify what is a suitable metric. Sometimes we might have an idea and we might change it because the data isn't as thorough as we would like it to be. Maybe there is an alternative that we should look into, but it's an iterative process to land on what is the final scope of metrics that we are going to use. (Interviewee#14)*

Interviewees also talked about how the maturity of information infrastructure and underlying data availability across different locales constrained what sustainability practices might be possible (Interviewees#4, 14). For example,

> *[A] big thing is maturity, which is how well can we actually respond to something. A really big issue at the moment is concrete and steel where there's heavy embodied carbon which has a huge impact on climate change. As an organisation, [company] isn't mature enough to respond to that because we don't have direct ownership of [concrete and steel supply data]. We also realise that the industry isn't mature enough for that. While it's a big material issue, we can't respond to that at the moment. You've got the same issue that faces the globe but the ways that we respond to that are very different. The UK's very mature [and] quite well ahead in the way that they respond and the data's already there. In other countries, they may not be that mature. Asia's got big issues. While in the UK substituting diesel might be quite easy because that market's quite mature, in Asia it's not. (Interview#9)*

The quotes illustrate the "iterative process" (Interview#14) by which aspects of infrastructural capacity such as data access, availability and 'thoroughness' can shape sustainability reporting practices, but also how demands for new metrics and regional practices, say from the UK, can prompt changes in corporate information infrastructure. We continue the analysis by highlighting key issues observed in generating sustainability reporting data.

Data derivation In describing the information infrastructure being used, practitioners indicated how sustainability data are often *derived* within information infrastructure. For example, given the infeasibility of weighing solid waste, firms may base their measures on extrapolated samples (McNally and Maroun, 2018; Project Transparent, 2021). Elsewhere, water consumption is also often derived from production levels based on internal estimates of the average water consumed per product unit, rather than measured directly through metering (Interviewee#4; WBCSD, 2019). Similarly, carbon emissions are not measured directly but generally derived from gas production and consumption levels. For example,

> *The way greenhouse works is we use that same system for the underlying data because emissions are really based on how much fuel have you used for your engines, for compression and all those processing plants. How much CO_2 is inherent in your product. When you've got gas and your gas might have 5% or 10% CO_2, you need to process that to make it into a specification that you can sell to the market. So, your source data comes from your production [which is] very rigorous. But when you think about emissions reporting, there's a lot of uncertainty. While in production, the uncertainty is relatively low because you've got meters and you know how much fuel was produced, for emissions, you don't measure those emissions. You derive that based on volume by composition, by*

temperature, so the uncertainty can be, let's say, five, 10, 15, 20% depending on what sort of things you're measuring. (Interviewee#3)

Our interview data accords with documentary evidence that suggests the uncertainty surrounding emission factors ranges from 5% for oil, gas and coal, to 10-15% for electricity given it is generally based on secondary data (WRI, 2015). Interviewees recognised that whilst derivation routines can facilitate preparation of some types of sustainability data, derivation itself can be subject to risks that limit how accurately data reflect the sustainability impacts they are intended to measure. For example, deriving water usage from the average water consumed per unit of product manufactured may fail to capture the context-specific impact of water usage (WEF, 2019).

Direct measurement challenges Given the challenges posed by direct measurement, many firms rely on billing information to infer usage of emissions or the use of natural resources. For example, reporting Scope 2 GHG emissions requires firms to assess carbon emissions from the energy they purchase (European Commission, 2019b; UNCTAD, 2019). Documentary evidence suggests energy usage can be based on the location from which energy is sourced (the average emissions factor of the electricity grid used for a defined time period) or based on the specific price paid for energy (using the specific emissions factor of the energy tariff used by the company that can be, for example, a green energy tariff) (Deloitte, 2020; FRC, 2021; UNCTAD, 2019).

Off-the-shelf sustainability data systems (e.g., CR360)[6] were used and often customised, that linked with utility billing systems to derive electricity and water consumption data. However, practitioners noted how billing data are inconsistent, particularly across numerous sites and timescales, and this often led to delays in gaining consumption data or a reliance on estimates or extrapolations which influenced data quality. For example,

In terms of the energy data, we were running on a bit of a spreadsheet system. We had a third party aggregating the data for us but now we have combined with procurement. It catches all the billable stuff but then there's a lot of bills or leases in the sites that might not get a bill around some of this data. We still need a process. We still need to manipulate it a bit to get to the real number, not to under-report. That's been a process we've been doing over the last six months. I was pretty happy with the data. It was just there was lots of small sites. And it's really hard to get things like water data for small sites, they don't get a bill. And to put the money in to get a meter in, it's not going to happen. So, we are having to estimate. (Interviewee#29)

Several firms employed third party providers who used robotic process automation to collect data from utility bills and subsequently populate sustainability data systems of companies, as confirmed in documentary data (KPMG, 2017a). For example,

Our utilities supplier, Energy Australia has a website where they automatically generate these bills. We've got our partner in the USA. They automatically log in using robots. They detect that there's a new bill there, it gets all the data ripped off automatically and then it gets integrated and sent to here [pointing to sustainability data system on computer screen]. (Interviewee#9)

[6] https://www.ul.com/resources/apps/360-sustainability; https://www.environmental-expert.com/software/sustainability-and-reporting-solution-448236

These quotes show the challenges that companies can encounter with direct usage measurement routines and, depending on artifacts used (e.g., customised spreadsheets or dedicated sustainability reporting systems), the risks to data quality that can lead to misrepresentative disclosures about sustainability and impair the reliability of cross-company sustainability performance assessments that form the basis of ESG scores and indices.

Commensuration Once sustainability data were collected, whether derived or directly measured, routines were used to commensurate source data into common, comparable, numerical measurement units. For carbon emissions, standard conversion factors aim to translate various greenhouse gases into emissions of carbon dioxide based on the energy that one ton of gas emissions will absorb relative to one ton of carbon dioxide. The derived CO_2 equivalents then provide the comparable measure of global-warming potential given that the warming effects of greenhouse gases all differ (Charnock and Hoskin, 2020; European Commission, 2019a; MacKenzie, 2009; Project Transparent, 2021; UNCTAD, 2019; Unerman *et al.*, 2018). Whilst the commensuration of Greenhouse Gas emissions is based on a standard conversion factor that translates data into metric tons of CO_2 equivalents (for example, the GHG Protocol or ISO 14064-1) other forms of commensuration are entity-specific. For example, routines convert data from a range of measures into common units such as power KWh, water flow m^3/s, hectares of land, kiloliters and dollars (see , Boiral and Henri, 2017).

Collating sustainability data was seen as challenging particularly when source data comes from different measurement systems which are often designed to report in different measurement units. For example,

> *I've found that accounts people don't interrogate the data enough. A good example of that is subcontractor reports, kilolitres instead of litres. They don't really put two and two together and kind of say, diesel for that particular subcontractor, they've used 100,000 litres, [but] it's actually only 100 litres or 1,000 litres which they've utilised. It's just that scale, if one decimal point is wrong, it's a massive difference for a business. (Interviewee#6)*

In line with documentary evidence, we find energy use data is collected from a combination of sources including utility meters, supplier invoices and statements (UK Government, 2019; WBCSD, 2019). Given that information infrastructure sources sustainability data in different ways, from direct measurement or derivation, across different units and parts of the business, the resultant aggregations were often seen as problematic (e.g., error-prone) (Interviewee#28). This was exacerbated by a lack of universal definitions and agreed assumptions behind calculations of key measures such as employee headcount or employee diversity that impaired comparability (CGI. and IIRC, 2020; IRTechnologyInitiative, 2018).

Indicators reported in sustainability disclosures were 'built' from disaggregated, commensurate elements that differed in their level of accuracy and precision. For example, the quote below illustrates how different water meters have very different levels of measurement accuracy.

> *Every asset has a different way of doing things. For example, most of the Cooper Basin was built 20, 30, 40 years ago. The metering on it is very different to our assets in Queensland that were built 5 or 10 years ago. When we're trying to work out the water use or the water extracted in the Cooper, it's a high-level engineering estimate plus/minus 50%. In Queensland, we know to the nearest 1%, at least for water. That's the difference*

in [the] water side. ... That's the best accuracy we have. The question then is if you add what you have in the Cooper and add what you have in Queensland, your level of uncertainty is very different. You've added two numbers that may or may not make any sense. (Interviewee#3)

The quote above illustrates direct measurement challenges associated with artifacts such as meters and the necessity for commensuration routines. However, lack of universal definitions and specific guidance suggests that commensuration routines are developed based on corporate judgement and discretion which can lead to variation in how companies address measurement challenges, which in turns raises questions about the reliability and comparability of information in sustainability disclosures.

Classification The aggregation of sustainability data also relied on classification processes being employed within companies. Data classification routines were key to constructing comparable sustainability data, but in practice such classification work relies on the interactions between human routines and technical artifacts (Interviewee#29). For example,

If you get down to looking at community donations or community investments, everyone uses different metrics. We can say that last year, we donated $115 million to the community. So, we would put us up there as one of the largest business donors. But it's very difficult to actually articulate that when you don't know what other people are putting in that data. Some people are putting data that we would think shouldn't be included. And they might think that we're putting in things that shouldn't be included. It's very difficult for external parties. So, they're looking at these reports and they're making judgements based on those, but they're not comparing like with like. (Interviewee#11)

Entering data into a database, they've got to select certain categories and sub-categories, and often you'll see them searching the wrong sort of category. And therefore… the reporting is not accurate. An example of that with grievance reporting on a mine site in Laos, which is where I was in February. I've helped them over a period of 6 or 7 years to get that right. But if you went back you'd be able to see the trends of grievances coming down in their reporting, because they were reporting so many things that weren't grievances, but they were just selecting that category in the database every time. They had 2 grievances last year, but if you went back 6 years, it would be 50-plus. (Interviewee#27)

The quotes above illustrate inconsistent application and use of classification routines both across companies and within the same company. This suggests that sustainability metrics based on data produced from these routines may not necessarily accurately reflect corporate sustainability impacts. The evidence not only raises questions about the reliability of the insights obtained from comparing sustainability performance across companies but also of assessing the same company over time.

After examining the different elements that constitute sustainability reporting information infrastructure, and the processes undertaken to collect data and produce reporting information, we consider how sustainability reporting information infrastructure interacts with practice. Addressing research question two pertaining to the nature and implications of the interaction between sustainability reporting infrastructure and sustainability reporting practices, the following section discusses the key role of regulatory compliance on this relation.

4.2 Regulatory compliance and implications on infrastructure and reporting practice
In considering what drives the development of information infrastructure and how this may afford or constrain different visions of sustainability reporting, our evidence suggests infrastructure development is shaped primarily by the need of companies to achieve regulatory compliance with specific sustainability reporting requirements. For example,

> *It starts around what's the minimum, in our business anyway. What's the minimum information that you need to understand for a project. Whether that's safety, financial, environmental. There are legislative requirements that you need to make. (Interviewee#10)*

In Australia, the Clean Energy Regulator administers instruments such as the National Greenhouse and Energy Reporting Act (NGER)[7] which stipulates corporate information requirements concerning the reporting of greenhouse emissions, energy consumption and production. Complying with legislative disclosure requirements of regulations such as NGER was an important infrastructural driver (Interviewees#4, 7). For example,

> *There's probably in excess of 800 large Australian businesses that report on a regular basis their carbon energy and emissions. Necessarily, there had to be systems built to actually effectively measure energy and emissions at a level of reliability that satisfied the reporting requirement imposed by government and was capable of being independently assured. (Interviewee#6)*

Consequently, regulatory compliance requirements shape the information to be reported, the data requirements, and the related supporting infrastructure. For example,

> *They [regulator] basically dictate the terms on what we need to collect. If there's changes in legislation, there's changes in what [data] you have to capture. (Interviewee#10)*

Given reporting information infrastructure is shaped by legislative demands, such infrastructural design affords and constrains particular types of sustainability reporting. Legislative demands influence the reporting boundaries applied. For instance,

> *We've got reporting boundaries that are applied. We have an entity level reporting framework that sets the boundaries of things that we collect, so what we do and we don't collect. So that way it's standardised at a global level, and then that's backed up by different reporting standards. In Australia, we use the NGER for energy, GHG Protocol, CRC [Carbon Reduction Commitment] in the UK and in the USA. That kind of gives us a good base and that gets collected up. (Interviewee#9)*

Below we discuss key emergent implications that arise as companies revise infrastructure in order to meet regulatory sustainability reporting requirements. Our evidence suggests that infrastructure extensions are developed to facilitate sourcing of sustainability data which are shifting the boundaries set by traditional financial reporting, but emerging sustainability reporting practices are shaped by development cost constraints.

Challenging traditional boundaries As reporting boundaries are shaped by legislative requirements, they do not necessarily fall within the responsibility boundaries dictated by

[7] https://www.legislation.gov.au/Series/C2007A00175

traditional consolidated financial reporting that are based on financial control. Due to the legislative influence, the resultant infrastructure does not constrain sustainability reporting within the lens of 'outside in' materiality. Legislation may require firms to consider their socio-ecological impacts beyond the narrow confines of traditional corporate reporting responsibilities, and collect sustainability data from supply chains, subcontractors and customers to measure metrics such as GHG emissions (CDP *et al.*, 2020a). Boundaries were often based on operational control or equity share, rather than financial control or dominant influence (CDSB, 2014; FRC, 2021; WBCSD, 2018a; WRI, 2015). For example, Scope 3 GHG emissions requires companies to collect data on the carbon emitted both up and down the value chain (European Commission, 2019b). Health and safety information is commonly collected on the basis of operational boundaries and management control (WBCSD, 2018a). To comply with such legislative demands, companies within complex and global value chains collected sustainability data from third parties who supported their operations but remained outside their direct financial control. For example,

> *90% of our work is subcontracted. We self-perform little bits but we wet hire in equipment. We'll get an excavator from one company, we'll get a grader from another company. Water carts, we might use our own or we might use another company to provide that. I'd say, 90% potentially of our actual non-financial data is really through subcontractors, potentially even higher. (Interviewee#6)*
>
> *Safety and wellbeing for the last two years has always been the number 1 priority, both from an external point of view and internal point of view. From the impact of [company], we have 35,000 direct employees and 70,000 contractors included and 90% of those people are on the road. We know that is the biggest exposure of any worker in Australia working on the road. Of course, safety and wellbeing are going to be a key. (Interviewee#14)*

Regulatory requirements for sustainability disclosures often mean that contractors must provide sustainability data to the company that engages them, if activities they carry out as part of the contract have sustainability implications. Collecting data beyond traditional financial reporting boundaries presented unique infrastructural challenges particularly where a company operates contracts across different jurisdictions which may have different sustainability reporting requirements.

In line with documentary data (WBCSD, 2019), practitioners talked about the challenges in allocating responsibility to contractors and routine variations to overcome their resistance to provide the required data, in the requisite format. For example,

> *The big thing for me, with subcontractors, it's building the relationship. First off, they're like, 'why do I have to do this [provide sustainability data]? I don't really want to do this. It doesn't add any value. I don't have to do it.' You can always point out the contract says you've got to do this, or you can say, look, what this is doing is actually giving us enough data to then look at trends over a period of time and it's a positive thing. So just get it done. (Interviewee#6)*
>
> *We capture the requirement to submit environmental information as part of a progress claim. That was a gateway for payment or a payment deliverable and that's typically tied into the contract as well. Not every organisation is going to follow that process. (Interviewee#10)*

In discussing those challenges, interviewees described how infrastructures had developed to collect data from many different sources. These developments included artifacts and routines that allow contractors to upload data (e.g., bill data) via dedicated portals using spreadsheet upload functionality or manual data entry. Infrastructure is also extended with routines to manage contractor payment conditional to the provisioning of the required sustainability data. For example,

> *We've got massive workforces on our construction projects and so the system's more tailored at that part of the business to focus on our subcontractors. They're the ones that drive the utes [trucks] or do the work. They consume all the energy and water waste data. So, it's [data system] more tailored to being able to give them access into our systems quick and fast so that way they can enter data without us having to chase them. That's tied to their pay. When they submit a payment, they need to tell us how much energy and water waste [was] used and that feeds into this system here. (Interviewee#9)*

Where infrastructure was developed to meet the needs of contractors, the routines introduced had to adapt to the user. For example, contractors used manual data collection routines and paper-based artifacts such as 'docket' forms to capture data. Although these presented data quality risks, information infrastructure was shaped by the needs of contractors who valued practicality and were more likely to engage with these artifacts and routines. For example,

> *We had a few buildings we had to knock down. For instance, if I go to February [demonstrating reporting system], we segregated all these materials on site and dispose of [them] separately. The tree stumps, asbestos, concrete, metals, steel and stuff. We use dockets for those. We were tracking all those. On this date we know what truck, who was the driver, what company, what type of truck, disposed where and type of material. The thing is you get those dockets and someone's in the office. Most of the time engineers get the docket. They created this spreadsheet and they just put it in there. We do this manually. I have to make it simple for the drivers and operators. I don't want it to get complicated and then confusing. It all comes from those dockets. (Interviewee#8)*

Our evidence again illustrates the socio-technical nature of information infrastructure– although more sophisticated technical artifacts were available, the infrastructure in use was adapted to the scale and needs of specific users, be they drivers, operators or subcontractors.

Responding to cost challenges Although information infrastructure was driven by specific legislative demands, which then afforded or constrained particular sustainability reporting practices, another key driver was cost. Practitioners talked about the cost of introducing and reporting new sustainability metrics and whether such cost was considered acceptable given the perceived expected benefits to the entity. Introducing and reporting new metrics can be costly and slow given the need for developments in underlying infrastructure. Developmental costs include upskilling of employees (or hiring of new employees), integration of new data required for new indicators into existing datasets, and update of analyses and reporting routines. For example, the detailed quote below illustrates the range of factors that contribute towards the cost of introducing a sustainability metric (or indicator) and the estimated magnitude of the cost to the entity represented by the interviewee:

> *We did some cost analysis. For every new [sustainability] indicator we place in the business, it costs us a million dollars. That's not just the system, but that's also the training, the skilling, employment, the getting people on the sites. It's identifying where the data's*

coming from, it's getting that in, it's marrying that with the wider datasets that we've got out there and then how does it get into the values and reports. I'll talk you through an example. One of the things we're looking at the moment is trying to understand how much concrete we consume. Concrete [has] massive environmental impacts from [a] carbon perspective. Before you actually start some sort of initiative or program to address that, you want to know how much you actually consume. So, you prioritise it. We have probably about 1,500 concrete suppliers around the world. We have different procurement systems that exist within different parts of the business. So, first thing is how do we actually find where all that data is with different systems that are used different ways. You have to go out and you have to research the company. You've got to understand how it's collected and then you either go, well, do we want to change the systems that are collecting that, that has flow and impacts to other functions such as procurement and finance. How do I bring all that data into one so I can then talk about aggregate level? Then you look at, well, how am I going to collect that data? Am I going back to getting spreadsheets or did I want to try and integrate that system automatically? You spend six months to a year doing that. The cost in getting someone to research that – through the roof. That's why I say it's hugely under-estimated, it's hugely expensive. But then, you and I would think, well, this is just natural information we should have at our fingertips, but it's not. (Interviewee#9)

Cost implications affected decisions about the extent to which some sustainability data are seen to be worth collecting and whether and the extent to which data produced and reported in the disclosures accurately reflect the company's sustainability concerns. Therefore, decisions to develop sustainability reporting information infrastructure traded off precision and materiality against costs, given reporting guidance often accepted that 100% data coverage was infeasible, and an acceptable percentage of omitted data should be based on its perceived impact on user decision-making (UK Government, 2019; WBCSD, 2019). Practitioners conceded that sustainability information was not expected to have the same level of rigour as financial information (Interviewee#3) and that information infrastructure was thereby constrained by the resources allocated (Interviewee#10). However, in new ISSB standards (IFRS S1), sustainability data quality is expected to be consistent with financial reporting data quality, and the nature and any sources of estimation uncertainty are to be disclosed (ISSB, 2023).

After considering how infrastructure is shaped by regulatory imperatives and costs, the analysis proceeds by examining research question three pertaining to how companies are seeking to develop information infrastructure, specifically looking at infrastructure integration and data quality.

4.3 Integration

Given that information infrastructure is largely driven by regulatory demands and costs, companies were generally found to have developed infrastructure comprised of a range of dedicated systems. These systems were generally separate and specialised around particular sustainability issues, enabling firms to comply with specific regulatory reporting requirements (Interviewees#2, 14). Many ERP systems in use contained modules designed to aid compliance with the requirements surrounding greenhouse gas emissions, or health and safety (SAP, 2019). For example,

We have a number of systems in place across the organisation, outside of the financial ones. We'll get health, safety and environment data through from a system called Enablon where individuals right across the whole of the business are inputting on a regular basis *any instances of incidents, injuries, things of that nature and contractors are also recording that information together with things like energy consumption, waste data, recycling data. Then we have records that will come through say from energy companies and then go into a platform called Envizi. Then we will also have fuel data coming through from the fuel provider. It's either going into spreadsheets and then into a system or it's going direct into a system. (Interviewee#16)*

The separation of different sustainability data systems was seen as a common problem among practitioners, and arose due to infrastructure developing historically along isolated 'legacy' pathways to meet separate legislative requirements that serve different purposes (Interviewee#19). For example,

We have lots of different systems, but they don't all fit together. We have systems for our greenhouse emissions, energy, and waste data. Then we also get data from our contractors regarding waste. We also use Sedex for ethical sourcing. Sedex is again separate. The systems are sitting everywhere. (Interviewee#11)

Although the integration of sustainability data systems is seen as an important source of insight, it has also been found to be challenging and potentially expensive to achieve by companies. In line with documentary evidence, regulatory sustainability data such as that linking to environmental health and safety regulation was difficult to reuse for sustainability reporting (NCC, 2019; Sobkowiak *et al.*, 2020). Integrating information infrastructure faces technical challenges due to different data management systems, organisational complexity challenges pertaining to reporting systems of operational units spanning domestic and international operations, and challenges related to human skills and the capacity to generate integrated insights (Busco *et al.*, 2018; SustainAbility, 2019). As reported in subsection 4.1, integrating systems relied on routines that ensured the consistent commensuration, aggregation and classification of data. Yet practitioners recognised that the consistent application of routines across multiple sites, encompassing different artifacts and actors remained a difficult challenge. For example,

We have recently acquired some large assets in WA. Their processes to measure, monitor will be very different to ours and we are currently in the process of integrating those. (Interviewee#3)

However, there was evidence of firms beginning to develop infrastructure to generate a more holistic view of how they impacted and were affected by moves towards sustainable development (Interviewee#14). For example,

[CR360 is] integrated with other systems that we use. For our health and safety data, we use Enablon. [Environmental and health and safety] systems are intrinsically linked so that… health and safety capital [and] environmental capital [keep] the same reporting boundaries... All the data that has already been harvested [is] put into a massive data lake [with] our other systems, such as our finance systems [and] our HR systems that collect [data on] our people, absences, sick days... That way we can talk more collectively about where our organisation is and see if there's links between our environmental data and our [finance or accounting] data and our people data. (Interviewee#9)

As illustrated in the quote above, infrastructure integration was seen by practitioners as a means to facilitate better understanding and measurement of the links and interdependencies between financial and nonfinancial factors in the company. Where evident in our dataset, the infrastructure integration efforts were underpinned by the companies' desire to enable better and more holistic analysis of sustainability reporting information. The following subsection examines how infrastructure is also being developed to improve data quality.

4.4 Data quality

Earlier sections illustrated many of the risks that were perceived to threaten sustainability data quality during sourcing and preparation. However, data quality is critical as it forms the basis for the production of useful sustainability metrics and disclosures. Practitioners highlighted how risks arising from data availability, data entry, data duplication, data lags, commensuration, integration and analysis were a source of concern. A key concern pertains to the verifiability of data, and to the infrastructural capacity to trace an audit trail cost-effectively (Interviewees#4, 10, 19, 28). In this subsection, we discuss how practitioners were developing or revising infrastructure to address data quality concerns via automation, audit and assurance.

Many practitioners described how they sought to automate aspects of the reporting process to improve data quality and reduce data errors associated with manual collection (see also , WBCSD, 2019). Routines that were predominantly reliant on manual, human intervention were perceived to be problematic, and a key threat to data quality, as detailed below.

> *Every year there will be quite a list of anomalies like the variances are greater than 25% from last year, and almost always it's a data entry problem. A lot of them come back to human error. It's data entry [that is] being completed at the site level. So, the site gets the bill. It goes straight into [sustainability system]. It's manual. I really want to get rid of that. That's key for me is to be able to improve data integrity. It's got to be automated. It's as simple as that. (Interviewee#4)*

> *Myself or our engineers get this data and then they put it in their spreadsheet so you see where the material goes. However, the spreadsheet's got lots of issues and errors. You know, human factors. I'll get an engineer to input that data, but is he reading it right from the docket, maybe not? That's the thing, every time we get a human involved, it can go wrong. (Interviewee#8)*

Efforts to develop sustainability reporting information infrastructure with routines that automate data collection are being introduced, but such automation is generally fragmented. In practice, automated routines and artifacts tended to be punctuated by manual routines to ensure data quality. Accordant with documentary evidence (SIIIT, 2020), it is common for entities to use a combination of infrastructural artifacts and routines, some of which automate data collection whilst others entail manual data entry. For example,

> *Some stuff [data collection] is automated, like electricity metering. There's some links off the meters back into [sustainability software] that says this was the consumption around energy. It's mostly energy ones that are interfaced. With the exception of the electricity metering, everything else is manually inputted. (Interviewee#10)*

Alongside the partial but increasing automation of data collection and input, other infrastructural revisions introduced new manual or automated routines to control data quality. These developments include constructing sustainability-based charts of accounts and data manuals that identified data owners and tolerable error levels for each indicator, with routines checking data anomalies such as omissions and longitudinal variation due to possible data entry errors (Interviewee#4; CGI. and IIRC, 2020; WBCSD, 2019). These routines, often described by practitioners as internal 'health checks', sought to systematically review data for issues arising from data entry, aggregation and integration (Interviewees#8, 14). For example,

> *What they [sustainability software provider] have done is include processes in the system. One is called data completeness. The system will check that there are no missing data. Let's say for example [this year]. It's already July. So, I should have in the system data from the month of January to June. Because there's a lot of files uploaded, probably the guy who uploads forgets to upload the file for the month of March. The system will pick that March data's missing. The system will alert you. There will be emails going out [and] the relevant people saying that the data's missing. The system also has a thing called data anomalies [where] the system will check the June… figure against [last year's] figure. They set a certain threshold. Let's say for example that the figures cannot be for more than 10% different. There's this trigger saying that there's something wrong with this data. Can you please check? If they did nothing wrong, no problem. If there's something wrong then what you do is you amend those figures. (Interviewee#28)*

Although audit and assurance were not required by Australian regulators for sustainability reporting, it was more commonly used in checking data surrounding legislative reporting on greenhouse gas emissions, health and safety and solid waste given the legal responsibilities and risks arising from errors (IRTechnologyInitiative, 2018; NCC, 2019). Many companies had also voluntarily introduced audit routines to enhance the "credibility" (Interviewee#3) of non-legislative sustainability disclosures. In some cases, this involved engaging external auditors for limited assurance of sustainability reporting routines including data sourcing, data owners, data collection controls, measurement, aggregation, conversion, consolidation and error evaluation methods (AICPA and CAQ, 2021; WBCSD, 2019). For example,

> *We engage [Big 4 firm] to do an independent verification of processes and mechanisms for reporting to get that layer of confidence that the systems in place are rigorous enough. … We do that every year and when we get that external validation we are confident what the system is spitting out and it's actually true, honest, reliable, complete, balanced, which is key for the things that we do. (Interviewee#14)*

Some practitioners had also introduced 'pre-assurance' routines when developing infrastructure to report new or expanded sustainability indicators.

> *For example, waste recycling two years ago. We worked with [Big 4 firm]. We prepared a basis of preparation on how the number is produced. What is the frequency? What is the boundary? We define all that with them and work with them to do a pre-assurance, not so much on the number but on the process, to get some clarity that everything we are doing is consistent with how we expect this number to be put together. That's year 1. Then year 2, that information is readily available for assurance, and we go and publish it. (Interviewee#14)*

Although there was recognition that sustainability data needed to be collected, processed and reported with the same rigour as financial reporting indicators (CGI. and IIRC, 2020; ISSB, 2023; Kaspersen and Johansen, 2016; WBCSD, 2019), the controls incorporated within sustainability information infrastructure lacked parity with those surrounding traditional financial reporting.

5. Concluding discussion

In the paper we have sought to improve current understanding of under-researched questions concerning the nature of the interaction between sustainability reporting information infrastructure and sustainability reporting practice, and the implications of this interaction. To this end, we have adopted a qualitative design to construct a dataset, based on interview and documentary evidence. We have analysed the dataset using the sociomateriality perspective of Pickering (1995) and operationalising the infrastructure conception of Leonardi (2011). Our analysis culminates with important findings that reveal insights into the relationship of information infrastructure and sustainability reporting practice and implications.

In addressing the first research question, *what sustainability reporting information infrastructure is employed in practice*, we highlight the nature of different artifacts and routines used by practitioners. We show how infrastructure is constructed through the inter-relations between material artifacts such as software applications and dockets and routines for data entry, commensuration, aggregation and data assurance. We identify some challenges companies face during data collection from multiple sites or human agents including contractors, the process of aggregating data from different sources and commensurating the data into common reporting units. We find that sustainability data were often derived, extrapolated or estimated, rather than measured directly, consistent with Kaspersen and Johansen (2016).

In addressing the second research question, *what is the nature of the interaction between sustainability reporting information infrastructure and sustainability reporting practices, and what are the key implications*, we demonstrate how infrastructure has been shaped by regulation and costs. Consistent with McNally and Maroun (2018), we find that infrastructure had been developed to meet specific legislative demands that required specific types of data, processing and reporting. Specifically, our evidence shows that artifacts including software and data entry forms and associated routines had been built around specific regulations mandating disclosure of issues such as carbon emissions, water usage, solid waste or employee health and safety.

Those aspects of information infrastructure that were designed around legislative requirements were generally well developed and mature. However, we also find that data collected to fulfil legislative reporting requirements were also used to support ‘voluntary’ sustainability reporting, and so infrastructural capacity developed around legislation shaped the nature of voluntary sustainability reporting that could be undertaken. This demonstrates that sustainability reporting information infrastructures can be flexible and support collection of data on corporate impacts from activity outside traditional reporting boundaries dictated by consolidated financial reporting requirements.

The key implication here is that information infrastructure can support double materiality-style sustainability reporting. Due to legal demands, sustainability reporting information infrastructure has not developed to be exclusively focused on collecting data and collating information related only to the issues that are deemed by the company to affect future enterprise value creation, consistent with the outside-in materiality perspective. On the contrary, the developed aspects of infrastructure such as those relating to carbon emissions, water, waste and health and safety focus on the impact of corporate activity *on* society and the environment, consistent with the inside-out materiality perspective.

Our findings also indicate how sustainability reporting information infrastructure was shaped by cost-benefit estimations. In developing non-legislative reporting infrastructure, the collection of precise sustainability data was often tempered by cost considerations which influenced the ability to derive or estimate particular types or sources of sustainability data. Costly infrastructure extensions such as dedicated sustainability reporting systems and direct metering to secure underlying data were seen to be comparatively harder to justify for non-legislative, voluntary sustainability reporting initiatives than for regulatory compliance purposes. This underscores the key, driving role of regulation in shaping sustainability reporting information infrastructure development, the reliability of sustainability disclosures, and reporting practice.

In addressing the third research question, *how are companies seeking to develop sustainability reporting information infrastructure*, our dataset highlights how practitioners sought to integrate disparate aspects of infrastructure and improve data quality via automation and quality control.

Integration remained a challenge given the more mature aspects of infrastructure had been developed and specialised around specific legislative demands, with commonly used software being dedicated to specific forms of reporting such as health and safety. Key sources of integration challenges pertain to technical issues due to a variety of data management systems, organisational complexity and human skills. To overcome these issues, practitioners were seeking to introduce enterprise-wide systems and common data repositories (or 'lakes') that could house sustainability data in accordance with specific legislation, 'outside in' reporting standards such as the ISSB, and 'inside out' reporting standards such as the GRI.

Companies have also sought to automate manual aspects of sustainability reporting information infrastructure to address data quality issues. For example, practitioners discussed automating data capture (e.g., pertaining to utility consumption data such as energy and water) and replacing spreadsheet data entry artifacts with dedicated sustainability reporting systems. Nevertheless, our evidence suggests that automation is generally fragmented and punctuated by human interventions, many of which were needed to check the data produced in automated processes. Consequently, achieving end-to-end automation across sustainability reporting information infrastructure remains elusive and, in its current state, may impair data quality.

Finally, we find that companies seek to address data quality concerns by introducing controls and assurance routines to identify data anomalies such as omissions or longitudinal variation due to data entry errors. Manual reviews were often used to assure automated processes, and similarly, automated controls were also used to assure manual processes. Although audits for sustainability reporting are used on a voluntary basis, our evidence shows how traditional assurance processes were being adapted in dedicated routines that provided 'pre-assurance' for new sustainability metrics and disclosures.

The discussion continues by developing contributions to our understanding of the relations between information infrastructure and sustainability reporting practice. By theorising information infrastructure as the sociotechnical arrangement of technical artifacts and social routines (Ciborra *et al.*, 2000; Leonardi, 2011; Troshani *et al.*, 2022), we demonstrate how sustainability reporting practices are shaped through the affordances and constraints arising from interactions between legislative requirements, users, technical possibilities and costs. In doing so, we consider the interaction between material and human agency in considering how 'machines' extend human capabilities whilst also restricting how those capabilities can be instantiated in practice (Pickering, 1995; Pütz, 2021).

The analysis identifies the infrastructural challenges and issues that shape the information reported in sustainability disclosures. We examine how data collection artifacts and routines are shaped by user needs, technical possibilities and costs where the information infrastructure in use develops around firm context. Cost constraints and technical capacities often led to the derivation or estimation of sustainability data rather than direct measurement. Rudimentary data collection routines were employed that were technologically unsophisticated but afforded the needs of thousands of contractors across broad areas of operations and supply chains. Data (un)availability, organisational complexity, measurement costs and associated technical challenges constrain how sustainability reporting disclosures accurately and comprehensively reflect the sustainability impacts that companies face, and equally, the companies' impact on sustainable development.

Our findings demonstrate the ways in which the disclosures presented in sustainability reporting are shaped by the information infrastructure that facilitates and supports their production. Whilst research has demonstrated the problematic nature of sustainability reporting disclosures (e.g. Accountancy Europe, 2019; Boiral *et al.*, 2019; Boiral *et al.*, 2021; Carp *et al.*, 2019; Cho *et al.*, 2015; Dagiliene and Šutiene, 2019; Soderstrom *et al.*, 2020; Talbot and Boiral, 2015; Tysic, 2021; WBCSD, 2019), extant literature has predominantly looked at the role of factors external to the organisation. By examining the role of information infrastructure, we offer insight into how internal dynamics and organisational context contribute to shape sustainability reporting possibilities. Sustainability reporting outcomes cannot be only reduced to explanations related to human intentionality such as goals and underlying reporting motivations (Pickering, 1995). A key implication of this contribution is that it highlights the active, constitutive role of reporting information infrastructures. We find that this role becomes evident in practice, whilst the infrastructure is *in use*. Whilst in use, human and technical agencies interact and infrastructure is extended with revised (or new) artifacts and routines, when existing infrastructure fails to support achievement of set goals. Whilst existing literature has demonstrated the constitutive role of information infrastructures more generally (e.g., Pollock and D'Adderio, 2012; Pollock *et al.*, 2018; Power, 2015; Power, 2019; Rowbottom *et al.*, 2021; Troshani *et al.*, 2022), our study contributes by providing a nuanced account of this role for sustainability reporting information infrastructures.

We analyse the role of derivation, classification, commensuration and aggregation routines that are specific to sustainability reporting. Given the costs of direct measurement and difficulty in expressing sustainability data in common measurement units, sustainability data are regularly constituted through derivation and estimation. Estimates from different sites and operations are aggregated with direct measures. Data are derived and commensurated into common reporting units such as equivalent tonnes of carbon dioxide (MacKenzie, 2009). Qualities are transformed into quantities (Unerman *et al.*, 2018). By aggregating data from different times and places, and transforming disparate forms of value into homogeneous units, commensuration reduces, simplifies and absorbs uncertainty (Chelli and Gendron, 2013; Järvinen *et al.*, 2022; Scott and Orlikowski, 2012). Whilst our evidence suggests that there are companies that carry out these routines rigorously, including audit and assurance of sustainability reporting, the practice is not uniform. This in turn, raises questions about whether companies can generate sustainability data whose rigour and reliability matches that of financial reporting data, as recommended in new ISSB standards (ISSB, 2023), and the extent to which comparisons across companies are reliable using reported sustainability metrics, ESG scores and indices.

In considering how infrastructure shapes what sustainability reporting may be possible, we highlight the role of regulation in driving infrastructure development. Regulation drives the need for the collection of specific and reliable data, and the associated information infrastructure. This has led many companies to develop an 'uneven' information infrastructure with mature artifacts and routines supporting the needs of specific legislative requirements, whilst infrastructure supporting non-legislative sustainability reporting remains comparatively underdeveloped. Consequently, the infrastructure supporting specific legislature such as carbon emissions, health and safety and solid waste has often developed along unitary trajectories and is often poorly integrated with the infrastructure supporting other areas of sustainability reporting that are aspirational to companies. The lack of integration is also exacerbated by lack of a common measurement unit that aids the commensuration, aggregation and consolidation of financial data across different systems. Despite the persistent calls for integration of the different forms of corporate reporting and its importance in assessing progress towards achieving the SDGs (CDP *et al.*, 2020a; ICAEW, 2017), different aspects of sustainability information infrastructure have developed along distinctly unintegrated pathways.

Given that information infrastructure has developed around legislative requirements, it is not necessarily constrained by financial reporting norms and therefore does not preclude specific visions of sustainability reporting. Current debates envisage an ISSB-style sustainability reporting that only reports on those issues deemed by management to affect enterprise value, or an European Sustainability Reporting Standards (ESRS)-style double materiality reporting vision that also discloses how corporate activity is affecting the planet and the environment, even where there is perceived to be no foreseeable impact on enterprise value (Rowbottom, 2023). Much of the debate supporting the ISSB vision, and corporate reporting boundaries more generally, is based on pragmatism and application (see, Hines, 1988) – sustainability reporting is only feasible and 'objective' if bounded by an 'outside in' materiality threshold based on perceptions of what might be relevant in assessing future value (CDSB, 2020a; CDSB, 2020b). As EFRAG (2021) note, "the application of costs and benefits assessments is more straightforward in the case of financially material matters" (p. 11). Beyond this traditional financial reporting boundary, it becomes difficult to decide what to report on the basis of 'inside out' materiality and impractical to collect reporting data. Financial accounting therefore acts as a gatekeeper constituting the corporate entity, by deciding what is inside, what is outside and what passes between as a 'transaction' (Roberts, 2021). Yet, sustainability reporting challenges this gatekeeper role in extending or redefining the organisational boundary. In this paper, we find that collecting data outside traditional financial reporting boundaries is not necessarily constrained by information infrastructure. On the contrary, due to legislative demands, information infrastructure supporting 'inside out' reporting based on impact materiality is often comparatively well developed. Furthermore, many of the software applications discussed by practitioners tended to be built around the reporting needs of standards extending beyond 'outside in' financial materiality such as GRI or ISO (Interviewee#28; INX, 2019; Visma Connect, 2021). Therefore, information infrastructure itself does not seem to constrain visions of reporting that encompass double materiality as promoted by the EU CSRD and codified in the ESRS.

Information infrastructure was also shaped by perceived costs and informational benefits, particularly for non-legislative reporting. Whilst more accurate sustainability data could often be sourced, the precision of sustainability data was tempered by its cost, and mediated by materiality. Collecting more precise and accurate sustainability data was often seen as unjustifiable where it was perceived to be immaterial to the judgements of information users or when the benefits of the improved data were perceived to outweigh the cost required to achieve improvements in data quality.

Without incentives to improve sustainability data quality equivalent with traditional financial data, and collect more precise sustainability data that is assured (as proposed by the EU CSRD) information infrastructure remains patchy and underdeveloped in areas.

Our findings have practical implications. Specifically, we highlight how the quality of underlying data supporting many sustainability metrics is variable and uneven, both between companies and within companies over time. Users and analysts of sustainability data may therefore exercise caution when making comparative judgements based on seemingly objective, commensurated numbers, scores and indicators. Understanding the interactions between sustainability reporting infrastructure and sustainability reporting practices can also offer practical opportunities and insight on how to develop information infrastructure in ways that can support corporate sustainability reporting goals and visions.

In closing the paper, we acknowledge the limitations of the analysis and conclusions. Set within an interpretive paradigm, the analysis relies on the coding and interpretation of the dataset that draws heavily on the views, experiences and perceptions of practitioners engaged in sustainability reporting. Further research can usefully explore sustainability reporting information infrastructure in corporate contexts outside Australia and trace how infrastructure develops in response to new regulatory demands and sustainability standards. Nevertheless, the broader sociotechnical arguments about constitutive capacity of infrastructure and implications on sustainability reporting practice underscore the importance of considering sustainability reporting information infrastructure in its own right.

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