Gordon Institute of Business Science
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Carbon assurance:

A structured literature review

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A research project submitted to the Gordon Institute of Business Science, University of Pretoria, in partial fulfilment of the requirements for the degree of Master of Philosophy in Evidence Based Management.

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Declaration

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Philosophy in Evidence Based Management at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

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Abstract

There are limited integratory studies on carbon assurance, as such literature is fragmented which hinders growth of scholarship. The review thus, seeks to consolidate and organise the formative literature in the multidisciplinary research fields of accounting, business, and management by investigating the approaches, themes, and the theoretical underpinnings of carbon assurance to guide future research.

The structured literature review uses a qualitative, inductive content analysis, to analyse themes from the data. Findings reveal four carbon assurance approaches, namely, carbon audit compliance, assurance of carbon management, assurance of governmental climate change, and assurance of greenhouse gas statement, the most discussed in literature.

The review further reveals awareness about climate-change and regulation of emissions as antecedents of carbon assurance. The practice improves credibility of carbon disclosures but is hindered by inaccurate measurement of carbon emissions. The approaches are theorised under stakeholder, stakeholder-agency, legitimacy theories, among others. The need to gain competitive advantage, recognition, and awards are some of the drivers of carbon assurance growth.

A narrow focus was placed on greenhouse gas emissions, hence, the social and environmental subject matters, as studied in the broad sustainability assurance were not reviewed. The review fills gaps in literature by identifying the approaches of carbon assurance, emerging themes, and theoretical underpinnings.

Keywords: Carbon assurance, Structured literature review, Inductive content analysis

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List of Abbreviations

AJG	Academic Journal guide
ABDC	Australian Business Deans Council
CDP	Carbon Disclosure Project
EU ETS	European Union Emissions Trading Scheme
GHG	Greenhouse gas emissions
IAASB	International Auditing and Assurance Standards Board
ISAE 3410	International Standards on Assurance Engagements (ISAE 3410)
ISAE 3000	International Standards on Assurance Engagements (ISAE 3000)
1SO 14064-3:2006	International Organization for Standardization (1SO 14064-3:2006)
UK	United Kingdom
USA	United States of America,
NGERS	Australian Government's National Greenhouse and Energy Reporting Scheme

Chapter 1: Introduction

1.1 Introduction to the Structured literature review

Proactive organisations are adopting strategies to mitigate climate change, carbon assurance is one of such strategies (Datt et al., 2020). Recent research suggests that the practice aids reduction of carbon emissions (Tang, 2019) by improving the credibility (Dutta, P. & Dutta, A., 2021), and quality of carbon emissions disclosures (Luo et al., 2023), which are susceptible to greenwashing tendencies (Fan et al., 2021). Previous reviews have focused on broader sustainability (Zhou, 2022), and carbon accounting (Ascui, 2014; He et al., 2022) literature, however, carbon assurance is distinct (He et al., 2022) and focusses on a narrower greenhouse gas emissions subject matter, hence, deserves a separate study (Datt et al., 2020). It is thus, imperative to conduct a structured literature review to understand the approaches, emerging themes, and theoretical underpinnings of carbon assurance.

1.2 Background

Carbon assurance is “a response to perceived legitimacy threats arising from more stringent carbon legislation and growing public awareness” (Datt et al., 2019, p.195). The practice is a strategic response to carbon mitigation (Bui & Fowler, 2019; He et al., 2022), and one of the four streams of carbon accounting, an independent, novel research field that advocates for the incorporation of new corporate accounting practices such as, carbon assurance into the traditional accounting practices to minimise global warming risks (He et al., 2022).

Although the initiation of this emerging, relatively new, and under researched practice (He et al., 2022), is not clearly highlighted in literature, it is estimated to have evolved in the year 2007, when Simnett (2007) critiqued the development of International Auditing and Assurance Standards Board (hereafter IAASB) which coincided with the introduction of the International Standards on Assurance Engagements (hereafter ISAE 3410) in 2012. Emergence of carbon assurance arose out of the need to improve accuracy, credibility of carbon disclosures (Ioannou et al., 2016; Simnett et al., 2009) but more so, the awareness about climate change exerted stakeholder pressure on firms to adopt strategies to reduce carbon footprint from their operations (Hoffmann & Busch, 2008).

Carbon assurance takes on four forms that are distinct in terms of purpose, scope, nature of assurance (Tang, 2019). These approaches include first, the greenhouse gas statement assurance, the most studied approach in literature, whose evolution coincides with the introduction of the greenhouse gas assurance standard and focusses on the verification of

greenhouse gas and energy emissions (Martinov-Bennie & Hoffman, 2012; Tang, 2019). Second, the compliance carbon audit that determines whether a firm's carbon emitting activities, are in line with the set carbon emission regulation. Third, the carbon management audit that determines the cost effectiveness of a project or firm's carbon management and internal control measures. Lastly, governmental climate change audit that evaluates the effectiveness of a nation's climate policy (Tang, 2019). Furtherstill, the term carbon assurance is used interchangeably for "carbon auditing", "greenhouse gas assurance", "climate-change audit" (Tang, 2019). Based on this ambiguity, it is thus, imperative to review the conceptualisation of assurance of carbon emissions and distinctions between the approaches.

Adoption of carbon audit is attributed to both external and internal factors (Zhou et al., 2016). For some (Mateo-Márquez et al., 2020) climate change pressures drive the adoption of new corporate carbon accounting practices, such as carbon assurance, to signal firms' responsiveness to reduce carbon footprint (Tang & Demeritt, 2018). While others suggest that external regulatory pressures also influence disclosure and assurance of carbon information (Comyns, 2018). Internally, high exposure to carbon risk increases stakeholder pressure (Datt et al., 2020) and drives high emitting firms, characterised by higher levels of carbon emissions (Datt et al., 2019) to disclose and assure their carbon emissions; consequently, minimising high stakeholder public scrutiny (Datt et al., 2018, 2019), and regulatory legitimacy threats (Rohani et al., 2023).

Carbon assurance improves the quality (Luo et al., 2023) and integrity of carbon emission reports (Bui et al., 2021), positively impacts firm value (Astuti et al., 2023; Mahmoudian et al., 2023), and significantly improves climate change (Dutta, P. & Dutta, A., 2021), environmental (Moroney et al., 2012), and greenhouse gas emissions (Mahmoudian et al., 2023) disclosures, however, there are more under looked consequences of carbon assurance in literature (Luo et al., 2023).

Carbon assurance is thus, relevant and its demand is increasing (Rohani et al., 2023), though marginally (Tauringana & Chithambo, 2015) for instance, Datt et al. (2018) note that 66 percent of firms from 44 countries assured their carbon emissions between the years 2010 to 2014, while Luo et al. (2023) note a current rise in carbon assurance from 65.7 percent in 2009 to 77.10 percent in 2017. Although this holds true, the practice is not immune to challenges. First, the voluntary nature of assurance in some jurisdictions (Datt et al., 2018; Rohani et al., 2023) speaks to slow adoption of the practice by countries and firms (Fan et al., 2021), for example Ryan and Tiller (2022), report that 51% of New Zealand firms do not assure their greenhouse gas emissions statements while only 4.73% of South African firms assure their carbon emissions out of a sample

of 44 countries reported between the years 2010 to 2014 (Datt et al., 2018). This expresses the skepticism surrounding the potential benefits the practice can add to the firm, country, and the whole world.

The skepticism and slow adoption of assurance of carbon emissions is secondly attributed to the expensive purchase of carbon assurance (Datt et al., 2020; Mia et al., 2019; Luo et al., 2023) especially for higher assurance levels (Rohani et al., 2023). Firms that contemplate adopting the practice, may have to conduct a cost- benefit analysis (Green & Zhou, 2013) to guide decision making. Sadly, if the costs outweigh the benefits, carbon assurance and thus, credibility benefits are foregone, but most importantly, efforts of achieving a net zero economy are slowed down. Although firms have an option to assure with less expensive specialist consultants than professional accountants (Zhou, 2016), there is still a slow adoption of the practice. The question left to ask is, what alternatives can a firm unable to purchase the expensive service use, given the limitations of voluntary disclosure of carbon emissions?

Some firms may thirdly opt to use internal auditors as alternatives to third-party assurance (Matsumura et al., 2014; Trotman & Trotman, 2015), while others, internally validate their carbon management statements (Kazemian et al., 2022) which further drags growth efforts. Is it however, right to equate information validation to carbon assurance, and are internal validating systems and procedures good substitutes for the external independent carbon assurance; but more so, how can we assess the credibility and quality of internal validation procedures without engaging external assurors? Some of these questions remain unanswered in literature, but evidence notes that only 44% of high emitting Australian firms audit their carbon management reports, moreover they prefer to use an internal carbon emission data validator because the internal systems accurately record carbon emissions, which nullifies the need for an external assuror, despite the differences between validating and auditing (Kazemian et al., 2022).

Carbon assurance is a relatively new practice (Simic et al., 2023; Tang, 2019), hence, the market is fourthly affected by a lack of uniform international assurance standard to guide this new form of assurance (Martinov-Bennie & Hoffman, 2012). This has greatly escalated assuror competition, ambiguity surrounding the most appropriate standard to use, consequently leading to a lack of comparison and consensus among the two groups of assurors (Mia et al., 2019). The absence of a uniform standard is caused by the unregulated carbon assurance market, which is different from the financial audit market that has uniform assurance standards, and principles for conducting financial audits (Fan et al., 2021). Carbon assurance standards differ by jurisdictions, for instance, in Australia, the Australian Government's National Greenhouse and Energy Reporting Scheme

(hereafter NGERS), regulates greenhouse gas emissions in Australia (Olson, 2010) while in America, Global Warming Solutions Act regulates carbon emissions in California (Martinov-Bennie, 2012). Overall, a lack of uniform assurance standard and regulation compromises the credibility of disclosed greenhouse gas statements (Olson, 2010).

Further still, the limited reporting and uptake of carbon disclosures, hinders the progress of carbon assurance practice. In support of this argument, evidence provided from New Zealand notes that only 74% of the sampled entities report their emissions, moreover, with a limited scope of assurance. This moderate disclosure, consequently, affects the credibility of disclosed greenhouse gas emissions, since greenhouse gas emissions disclosures are inputs for any carbon emissions initiative (Green & Zhou, 2013) making carbon assurance an outcome.

Despite the practice being relatively new and coupled with the limited disclosure, the carbon assurance market is highly diverse, competitive, and unique (Knechel, 2021; Xu & Andrew, 2021) though diversity brings with it associated challenges, for instance, firms must choose between two dichotomously categorised groups of assurors namely, accounting, and specialist firms (Huggins et al., 2011; Rohani et al., 2023). As if that is not enough, the assurors use different assurance standards (Huggins et al., 2011) and some (Rohani et al., 2023) further assert that, accessing assurors in this market is challenging. Assuring carbon information is thus, diverse but not straight forward, compared to the traditional financial auditing (Green & Taylor, 2013; Olson, 2010; He et al., 2022). Carbon assurance combines two important matters, namely carbon, as a climate- related subject matter whose expertise is held by scientists and assurance, an expertise originally inclined to professional accountants (Ekasingh et al., 2019). This means that assurance of carbon disclosures, requires both assurance and technical expertise (Simnett et al., 2009). This however, leaves a further challenge, who then should assure carbon emissions disclosures?

There is a disagreement in literature, about the right assurance provider to undertake carbon assurance (Huggins et al., 2011; Knechel, 2021; Lodhia & Martin, 2012; Xu & Andrew, 2021). While accounting assurors assert that accounting firms are the rightful assurors to verify carbon emissions statements, given the transferability of audit skills and concepts from financial audit to carbon assurance (Martinov-Bennie & Hoffman, 2012), in contrast, non-accounting assurors suggest that specialist consultants can perform an equally good job, given their expertise in the subject matter of carbon emissions (Busch et al., 2023; Datt et al., 2020; Dutta, P. & Dutta, A., 2021). Regardless of this, each assurance provider brings vast knowledge and competence from his area of expertise and as such, literature notes that assurance teams often engage external experts, who are knowledgeable in the assured subject matter (Green & Taylor, 2013; Huggins et

al., 2011) to fill skills deficiencies in assuring scope one emissions (Huggins et al., 2011). Multidisciplinary greenhouse gas assurance teams, hence, encourage complementing assurance with technical expertise (Huggins et al., 2011), however, these teams are also not perfect, hence assessing their effectiveness in the assurance practice is crucial (Kim et al., 2016). Are multidisciplinary greenhouse gas assurance teams the solution to the several challenges facing this new carbon assurance market, or should assurance be undertaken by separate assurance firms?

In a bid to overcome some of the challenges facing the evolving carbon assurance market, a Greenhouse gas emissions International Assurance Standard (ISAE 3410) according to Green and Taylor (2013), was introduced by International Auditing and Assurance Standards Board although scholars disagree about when the standard was introduced, for instance, while Green and Zhou (2013), assert that the standard was released in the year 2012, on the other hand, Tang (2019) and Datt et al. (2019), note that was implemented in 2013, although they all agree that the standard guides the assurance of greenhouse gas emissions (Datt et al., 2019; Green & Zhou, 2013; Tang, 2019). Nevertheless, introduction of the standard has however, not marked the end of the many challenges facing this growing market (Fan et al., 2021).

In sum, carbon assurance reduces greenwashing tendencies, hence, it improves the credibility of carbon disclosures. Several theories are used in literature to explain the carbon assurance phenomena such as stakeholder, legitimacy, credibility enhancing, institutional theories, among others, however, there is limited integration of these theoretical lenses to help us understand the phenomena better. Nonetheless, demand for carbon assurance is increasing amidst claims of the costly, voluntary practice, partly attributed to the formative practice and lack of a uniform assurance regulation.

1.3 Problem statement

Carbon assurance is a promising research field (Fan et al., 2021) and literature indicates that it improves the credibility of carbon disclosures. Although this is true, the practice is emerging (Rohani et al., 2023), voluntary (Matsumura et al., 2014), considered expensive by some (Mia et al., 2019), but more so, literature is scanty on most topics (Knechel, 2021; He et al., 2022) for instance, although Zhou et al. (2016) examine the drivers of carbon assurance, there are still some unexplored factors, moreover, the practical implementation of carbon assurance process

(Knechel, 2021) and the approaches, emerging themes, and the theoretical underpinnings are unknown.

These knowledge gaps are partly attributed to the multidisciplinary nature of greenhouse gas assurance (Ekasingh et al., 2019; Knechel, 2021). The assurance of greenhouse gas statements requires assurance, scientific, and technical knowledge, which culminates into a multidisciplinary construct conceptualised differently under accounting, business, engineering, and science domains. Integration knowledge from multiple domains hence becomes difficult.

Further still, although the growing relevance of carbon assurance has attracted the attention of scholars (Dutta, P. & Dutta, A., 2021), most empirical studies focus on the drivers (Zhou et al., 2016), a few on outcomes, or the challenges facing the practice (Olson, 2010). There is, hence, a need to integrate this fragmented literature into one review to direct future research.

Moreover, carbon assurance terms vary across jurisdictions and contexts (Green & Zhou, 2013; O'Dwyer & Owen, 2005; Ryan & Tiller, 2022; Tang, 2019; Tang & Luo, 2014) and although literature recognises four approaches of carbon assurance, greenhouse gas statement assurance, is however, the most studied in literature, while giving little focus on the rest of the three approaches. Mindful of the fragmentation of literature, the multidisciplinary nature of the construct, the differing terms and conceptualisation of carbon assurance, approaches, and theoretical underpinnings used in the research field, a structured literature review is thus, imperative to organise the literature, direct future research to reduce the scanty of literature.

1.4 Prior studies

There is currently no study that has independently and specifically reviewed literature on carbon assurance, as far as my engagement with literature is concerned. Although three studies have reviewed other climate-related, sustainability, and carbon accounting literature as illustrated in **Table 1**, none of the reviews attempts to define, examine the approaches, emerging themes, and theoretical underpinnings used in the carbon assurance research field.

Zhou (2022) gives a broad review of climate-related, and sustainability information and thus, does not narrowly focus on carbon assurance, moreover, the review focuses on the Australian context and hence, under looks publications in other jurisdictions. Similarly, He et al. (2022) reviews carbon accounting literature published until the year 2018, while focusing narrowly on the accounting domain, but does not narrowly and specifically focus on carbon assurance, a carbon accounting stream. In comparison, Ascui (2014) also reviews carbon accounting papers published between the years 2003- 2013, but reviews only two carbon assurance papers. Therefore, it is

imperative to independently conduct a structured literature review on carbon assurance because none exists to the best of my knowledge.

Table 1: *Prior literature reviews summary*

Reviewer	Type of review	Purpose of the review	Review period	Scope of the review
Ascui (2014)	Literature review	To examine carbon accounting literature	2003-2013	89 papers
He et al. (2022)	Systematic literature review	To review the practice of carbon accounting	2005-2018	117 papers
Zhou (2022)	Archival	To review and synthesise the findings on climate related and sustainability information	2009-2021	Not mentioned

Source: Author

1.5 Study rationale

Based on prior reviews, this structured literature review makes four contributions. First, assurance of carbon matters (Datt et al., 2019; Mahmoudian et al., 2023), although well studied in other fields like Economics (Metcalf, 2020), we know little about how it affects accounting, business and management. The review thus, consolidates and organises the formative (Datt et al., 2020) and scanty (He et al., 2022) carbon assurance literature, to grow scholarship in the accounting, business, and management fields by highlighting the currently researched themes, while drawing attention to the least researched themes, to guide future research areas.

Second, the review builds scholarship by distinguishing carbon assurance as a distinct form of non- financial assurance, besides the broader assurance of sustainability information, and the traditional financial assurance, by tightly focusing on greenhouse gas emissions, a specific subject matter (Datt et al., 2020).

Third, the review answers calls made in literature to; investigate carbon assurance approaches (Chatterjee, 2012), increase our understanding of the differences between carbon assurance and financial audit (Luo et al., 2023), research about the avenues carbon accounting can mitigate climate change (Gibassier et al., 2020), and the challenges surrounding carbon assurance (Matsumura et al., 2014).

Fourth, the review re-echoes to policy makers, the need to mandate carbon assurance given the greenwashing incentives among managers, and to urgently institute uniform regulations of greenhouse gas assurance to improve the practice. Lastly, the review provides accountants and non- accountants with practical guidelines of improving carbon assurance, carbon accounting, and management practices. In sum, the structured literature review sought to organise the

research field by examining the definition, approaches, current themes, and theoretical underpinnings in literature, while highlighting the distinctive nature of carbon assurance from other forms of assurance, to guide future research and practice.

1.6 Review questions

To accomplish the above objectives, a structured literature review is adopted to evaluate the carbon assurance research area (Snyder, 2019). Previous reviews note that carbon assurance is multidisciplinary, thus, conceptualised differently and studied under different contexts (Ekasingh et al., 2019; Knechel, 2021), hence, to structure (Rousseau et al., 2008) and build on previous work, the review aims to answer.

a) What are the approaches used in carbon assurance engagements?

There are three forms of carbon assurance besides verification of greenhouse emissions disclosures (Simnett, 2007). Firms may secondly, seek to check for compliance with climate-change regulations (Chatterjee, 2012; Green & Zhou, 2013) or thirdly, to determine the cost effectiveness of a project or firm's carbon management controls. Lastly, to evaluate the effectiveness of a nation's climate policy (Tang, 2019). Despite this understanding, literature is silent about the other three approaches of carbon assurance, and mainly focuses on greenhouse gas emissions assurance, thus it is imperative to investigate this review question.

b) What are the emerging themes in carbon assurance?

Empirical studies in the carbon assurance field independently focus on several themes, it is thus important to synthsise all studies (Snyder, 2019), to establish the emerging themes in literature.

c) What are the theoretical underpinnings in carbon assurance?

There are several theoretical lenses used to explain the carbon assurance phenomena. There is, however, no single study that has overviewed all the theories used, this review thus, seeks to bridge this knowledge gap.

1.7 Structure of the report

The next sections of the report will follow in this order; the second chapter outlines the selected research methodology, to guide the review, as well as the justifications for the choices made. The third chapter discusses the literature in multidisciplinary fields. The fourth chapter details the review findings, and the fifth chapter outlines future research areas, review limitations, and the conclusion.

Chapter 2: Methodology and Analysis

2.0 Introduction

The objectives of the review were to examine the forms, concepts, and theoretical lenses in carbon assurance literature. To accomplish this, a structured literature review (SLR), “a method that examines a body of scholarly literature, to develop insights, critical reflections, and future research paths” (Massaro et al., 2016, p. 2) was used. An SLR was adopted because, first, carbon assurance is an emerging construct (Datt et al., 2020) thus, a bibliometric analysis was not feasible for a small sample (Donthu et al., 2021). Second, SLRs are appropriate for constructs conceptualised differently, by different disciplines (Wong et al., 2013) thus, the multidisciplinary nature of carbon assurance construct (Knechel, 2021), required adoption of an SLR. Third, to increase the number of studies using structured literature review as a methodology in the accounting domain (Massaro et al., 2016).

A three-stage process which included planning, execution, reporting, and dissemination of review results was followed (Tranfield et al., 2003). In sum, the review sought to organise the research field by scoping for previous reviews to set the search boundaries before searching and selecting the appropriate sample using an inclusion criterion. Selected articles were read in full to assess their relevance before inductively drawing meaning from textual content data, to give account of the themes and abstract data for descriptive analysis as discussed below.

2.1 Stage one- Planning the review.

A protocol to identify review articles (Gupta et al., 2020) was first drafted, followed by scoping, to search for past carbon assurance reviews in accounting, business, and management research fields. This was carried out to gain familiarity with the concepts, audience, potential contribution (Snyder, 2019), and set the review boundaries (Tranfield et al., 2003).

Scoping of prior literature reviews revealed that, Zhou (2022) focused on Australian publications, climate-related, and sustainability information thus, knowledge gaps, in consolidating literature from other jurisdictions, and on greenhouse gas emissions, a narrower subject matter of sustainability (Trotman & Trotman, 2015), was identified. Similarly, He et al. (2022) reviewed all literature published in carbon accounting, until the year 2018, without solely focusing on carbon assurance, one of the four streams of carbon accounting (He et al., 2022), and a component of sustainability assurance (Datt et al., 2020), as shown in **appendix 1**. A need to keep track of the

current themes in the carbon assurance was hence, identified, and lastly, Ascui (2014) reviewed only two papers published on carbon assurance, while similarly focusing on carbon accounting.

“Carbon assurance” was not explicitly defined in literature, and in most cases, the term was used interchangeably with “carbon auditing”, “greenhouse gas assurance” (Tang, 2019). The definition, nonetheless, helped to set the conceptual boundaries of the search. To depart from the review conducted by Zhou (2022), all publications across the world, and all methodological approaches were considered.

2.2 Stage two- Conducting the review.

2.2.1 Search strategy

A search plan to identify keywords, search databases, and journals was first drafted (Adams et al., 2017). Search keyword combinations listed in **appendix 2** earlier identified in the protocol (Tranfield et al., 2003) were used.

Keywords were combined because carbon assurance comprises of two issues namely: “carbon” and “assurance” thus, it was necessary, to combine key words used interchangeably for each of these terms. Tang (2019) confirms that “carbon auditing” is used interchangeably for “climate change auditing”, similarly, Tang and Luo (2014), Ryan and Tiller (2022) agree that “carbon” includes, “greenhouse gases”, “carbon dioxide”, “carbon dioxide equivalent”, moreover, O’Dwyer and Owen (2005) assert that, “assurance” is used interchangeably for, “assuring”, “assurance”, “auditing”, “verification”. Second, the keyword combinations were essential to ensure a comprehensive, high quality, and relevant sample (Tranfield et al., 2003).

Searching for articles thus, involved aggregating all concepts of the tightly defined construct, because first, although assurance of carbon emissions is part of assurance of sustainability information (Datt et al., 2018), there was need to distinguish it from the latter. Second, carbon assurance is an emerging practice (Datt et al., 2020), with scanty literature (He et al., 2022), hence, to increase the number of articles, I reviewed literature published between the years 2007 to 2023.

Emerald insight, Scopus, Science Direct, and Google scholar databases were used in the search for three reasons. First, Scopus is a high-quality, easily accessible database with an extensive collection of articles (Donthu et al., 2021) in line with the review questions. Second, much as Emerald insight, Science Direct, and Google scholar are aggregators, they are useful in previous reviews searches (e.g., Borghei, 2021; He et al., 2022). Third, I wanted to have an all- inclusive

collection of articles (Linares- Espinos et al., 2018), and to minimise bias of selecting articles from one database.

2.2.2 Search criteria

A trial search using the identified keywords, databases, and eligibility criteria (Snyder, 2019) established under the protocol was first conducted before the actual search; to evaluate the feasibility of all components of the protocol, and to make changes, where necessary to the key words. Using Snyder (2019) as a review methodological guide, identification and selection of the articles was conducted using the following two steps.

A. Identification of the sample

Purposive, judgment sampling, a qualitative, non-probability sampling approach, that involves selecting a sample, based on a given selection criteria, and reviewer's judgement (Suzuki et al., 2007) was used to identify the sample; because, first, a structured literature review is a qualitative research design, hence, a qualitative sampling method was appropriate. Second, a strict selection of articles that studied greenhouse gas emissions, and not climate, social, and environmental subject matters (Datt et al., 2020), required a reviewer's judgment.

The sample included papers published on carbon assurance topics drawn from the accounting, business, and management journals, from the years 2007 to 2023. The search was conducted from multidisciplinary journals; to take note of the multidisciplinary nature of the construct, conceptualised differently in those three disciplines, second, to increase the sample size, given the scant literature available on the construct (Luo et al., 2023). Although the evolution of carbon assurance is not clearly documented in literature, the growing awareness of the construct, is estimated to have started as early as 2007, when the first publications by Ratnatunga (2007), Simnett (2007), Simnett and Nugent (2007) critiqued carbon auditing, IAASB and assurance standard for greenhouse gas emissions disclosures respectively, which coincided with the commencement of the greenhouse gas assurance standard (IAASB, 2012), and was later finalised in 2013 (Datt et al., 2019, 2020).

Keyword combinations like; "greenhouse gas AND assurance OR audit OR auditing"; "carbon AND assurance OR audit OR auditing", were adopted in the search, using the Boolean features "AND", "OR", to comprehensively identify (Mamabolo & Myres, 2020) carbon assurance articles. A search form in **appendix 3,** was also used to record the initial search results.

B. Sample selection

The following three- step screening criteria was used to arrive at the appropriate sample size.

a) Initial screening based on title, abstract and keyword.

Given the extensive search, I further screened the results using the title, keyword, and abstract criteria, to save time (Mason, 2010), and minimise reading all searched articles. The title, abstract, and keyword form in **appendix 4** was used to select, and document the results. Articles that met at least one of the three listed criteria, were selected and their abstracts were further read, to refine the sample (Gupta et al., 2020). Abstracts that discussed themes like, approaches, drivers, theories of carbon assurance, were selected, while those that discussed broader themes in sustainability assurance and financial audit literature were rejected. An evaluation form in **appendix 5**, was used to select articles according to their abstract relevance, and availability of screening criteria in the respective databases (He et al., 2022).

b) Inclusion and exclusion criteria.

The quality of articles was considered as the first criteria, where peer-reviewed articles from high quality ranked journals, assessed using Academic Journal guide (AJG) 2021 and the Australian Business Deans Council (ABDC) 2022 lists were selected. The AJG has journals published in multiple disciplines like accounting, business, and management, subjected to editorial and expert judgement, and peer-reviewed every after three years, to ensure that the quality of journals included therein, meets the threshold. Similarly, ABDC is a collective effort by Australian Business Schools that publish a journal quality list, to improve research quality (He et al., 2022).

These two lists of journals ranking were used to guarantee a good article quality, second, because, they are highly recommended by faculty, as journal guides, for selecting quality research output, and third, because the researcher is a business student, undertaking business-related research, hence, it was appropriate to use journal lists that publish business and management journals. However, although most selected articles were published in journals listed on the AJG 2021 and ABDC 2022 lists, three papers from unlisted journals were selected because carbon assurance is a new construct (Simic et al., 2023).

The second criteria for selecting the review articles thus, focused on all conceptual and empirical peer reviewed carbon assurance articles and published in high impact accounting, business, and management quality journals like, The Accounting review, Accounting, Auditing and Accountability Journal, and rated 4*, 4, 3 and 2 (AJG) 2021 and A*, A and B (ABDC) 2022, April 2023 version. This was carried out, first, to increase the scope of the search, given that carbon assurance is a multidisciplinary construct (Knechel, 2021), has emerging (Rohani et al., 2023), and scanty (Datt

et al., 2018) literature. Second, articles published in these journals go through a rigorous, high quality, peer reviewed assessment process, hence, it was easier to assess the articles' relevance to the review questions using their abstracts and inclusion criteria. Only one paper (Ascui, 2014) ranked 1B was included in the review, despite being below the study's 2 (AJG) 2021 and (ABDC) 2022 ranking selection criteria, because it is a commonly cited literature review paper, and has offered a framework on which the carbon accounting literature is organised.

The review also included conferences papers and working papers to increase the scope of the sample and minimise having a thin dataset (Morse et al., 2002; Snyder, 2019). Although criticised for the lack of rigorous peer review quality checks (Gupta et al., 2020), conference papers are easier to read, contained current, relevant information pertaining to the themes in the carbon assurance which contributed to the richness of the SLR, hence, reduced the bias of using only articles published in scientific journals (Adams et al., 2017).

Articles published between the years 2007- 2023 were selected for two reasons. First, although a structured literature review is not meant to review all articles published about a construct (Snyder, 2019), this review is an exception. Drawing back to the first publications helped the reviewer overcome the challenges of a small sample size given the scant literature. Second, although a five-year recency period is recommended by faculty, carbon assurance is still an emerging construct, thus, the review sought not only to historically overview the construct, but to also give an overview of the current themes in the literature (Snyder, 2019). Third, as earlier indicated, the development of carbon assurance commenced in 2007, and coincided with the commencement of the greenhouse gas assurance standard (IAASB, 2012).

English articles were selected because, of the author's familiarity with the language. Second, it is widely used in scientific research (Linares- Espinos et al., 2018). Third, English articles are easily accessible, which saved search time. Articles published before 2007, written in other languages besides English, as well as those published in journals ranked below 2 according to (AJG) 2021 and (ABDC) 2022 except for Ascui (2014) were rejected, to guarantee an excellent quality sample.

Citation counts were used as a supplementary check, to ensure that selected articles had a high impact in the research field, despite the criticism surrounding this quality measure (Massaro et al., 2016). Articles with at least five citations per year were selected (Mamabolo & Myres, 2020) while loosening the requirement for articles published in 2021, 2022, and 2023. Google scholar generated the list of citations per year, outlined in **appendix 6.**

A study eligibility form that included the subject area, document type, publication stage, language, publication years and the source title (Linares-Espinos et al., 2018) outlined in **appendix 7,** was used for each of the selected articles, to identify papers to be forwarded to the next steps of the review process. Articles that met this criterion were then selected, downloaded in PDF versions, and then imported to Mendeley, before being forwarded to the next step of the review process, because Mendeley deletes duplicate articles, and is very handy with referencing.

c) Full text reading

Selected articles were then read in full, to ensure alignment with the inclusion criteria (Snyder, 2019) and relevance to the review questions, because titles may mislead (Rousseau et al., 2008). The researcher discarded articles that discussed issues outside the greenhouse gas subject matter, and the final sample size was 52 articles. **Table 2** outlines excluded, and selected articles.

Table 2: *Sampling criteria, searched, included, and excluded review articles.*

Stage	Selection criteria	Excluded articles	Included articles
1.	Initial search results		32,653
2.	Publication years (2007-2023)	6,975	25,678
3.	Subject area (accounting, business, economics, finance, and management)	21,949	3,729
4.	Document type (research articles, conference papers)	2	3,727
5.	Publication stage (final)	1	3,726
6.	Language (English)	1	3,725
7.	Source/publication title	905	2,820
8.	Carbon assurance focus	2,749	71
9.	Duplicates	19	52
10.	Articles left		**52**

Source: author

2.2.3 Data abstraction

Microsoft excel spreadsheets modelled as data extraction forms were used to, abstract information from the 52 articles (Atewologun et al., 2017; Gupta et al., 2020), provide an audit trail of all extracted information (Pratt et al., 2020) for purposes of transparency, replicability, analysis (Rojon et al., 2021), and minimise mistakes during abstraction (Tranfield et al., 2003).

The review questions, descriptive analysis information, and the thematic structure influenced the components of the data abstraction forms (Rojon et al., 2021; Tranfield et al., 2003). Four categories of information were thus, populated into the excel spreadsheets. The name of author, and publication year, were kept constant for all categories, for easy identification of articles. The categories were, first, bibliographic information namely, article title, name of journal, journal rank, discipline, purpose of the paper. Second, detailed description of papers namely, the general research topic, research setting, and continent. Third, methodological information namely, the

research methods, and key findings. Fourth, other information namely, theoretical underpinnings, reviewer's reflection, and gaps in research. **Appendix 8** to **appendix 11** illustrate the extracted information. All the above-mentioned information was extracted, and recorded into separate excel spreadsheets to ease analysis, coding, and synthesis of the data. The data was then checked for similarities, and differences were reconciled, to reach an agreement about the categorisation, for each of the four categories, across the review papers. The researcher summarised, and reported the findings in tables, graphs, and charts, to ease reader comprehension (Tranfield et al., 2003) and give a visual analysis and description of carbon assurance field, as discussed below.

2.3 Stage three- Reporting

2.3.1 Descriptive analysis

Table 3. shows the number of carbon assurance articles reviewed between 1st January 2007 to 31st October 2023. A fluctuating trend in publications is recorded in the review period. Three publications were released in 2007, however, there was a fall in 2008. After which 2 constant publications were recorded between the years 2009 to 2011. The year 2012 registered the first peak of 5 publications, before a drop in 2013. A constant number of publications is noted for the years 2015 and 2016. Zero publications were recorded in 2017, however, the years 2018 to 2020 recorded a rise despite covid-19 pandemic challenges, before a constant drop in publications in the years 2021 and 2022. The year 2023 has registered the highest number of publications. Carbon assurance is an emerging construct; thus, fluctuations are expected, and as scholarship grows, more publications are likely to be recorded.

Table 3: *Carbon assurance studies across the review period*

Year	Frequency	Percentage (%)
2007	3	6
2008	0	0
2009	2	4
2010	2	4
2011	2	4
2012	5	10
2013	2	4
2014	4	8
2015	3	6
2016	3	6
2017	0	0
2018	3	6
2019	4	8
2020	5	10
2021	4	8
2022	4	8
2023	6	12
Total	**52**	**100%**

Source: author

Figure 1 shows carbon assurance publications over the review period. The trend shows fluctuations in the number of publications from 3 publications in 2007 to 0 publication in 2008. Peaks are registered for the years 2012, 2020, and 2023 with the highest number of publications. A decline in publications were registered between the years 2014 to 2017, before a steady rise between the years 2017 to 2020, a drop and a constant in 2021, 2022, and a rise in 2023.

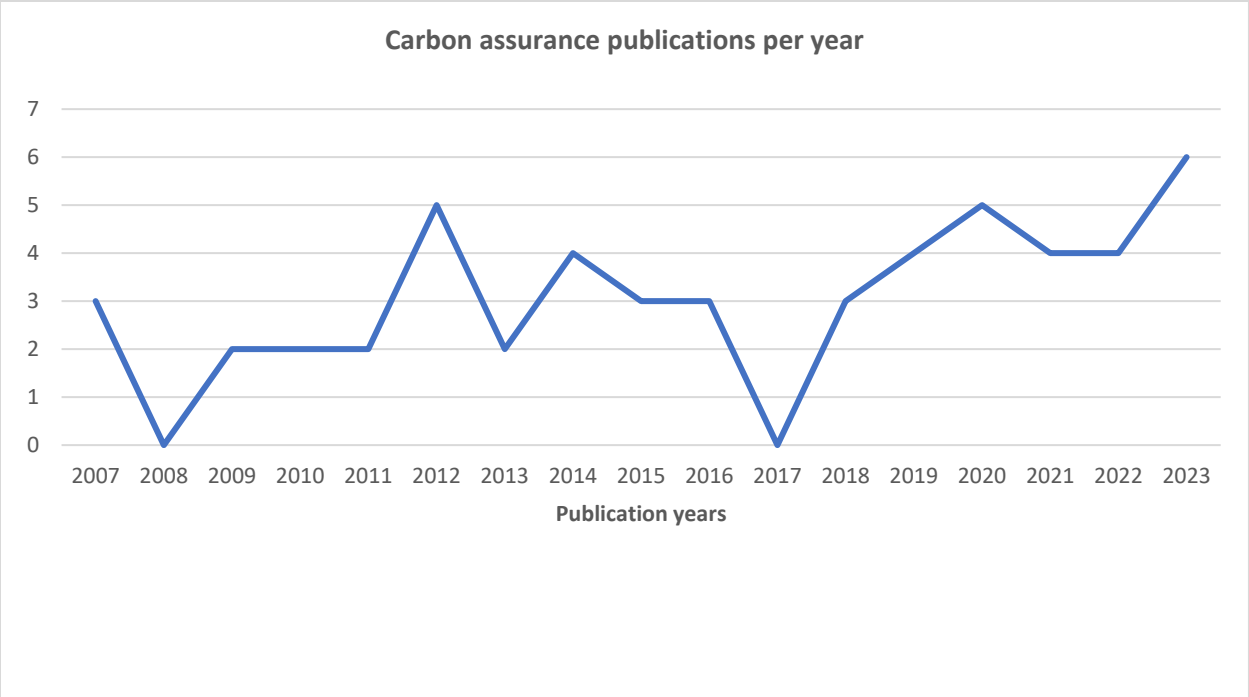

Figure 1: *The trend of carbon assurance publications*
Source: author

The research methodology used in carbon assurance studies is illustrated in **Table 4**. Results show that majority of studies are empirical and use quantitative research methodology, followed by qualitative, theoretical/conceptual studies, and mixed methodologies with the least representation. A significant number of conceptual papers are registered in the earlier years of the construct, attributed to the nascent stage of construct development (Simic et al., 2023), however, the carbon assurance market has started maturing and is gaining scholars and policy makers attention, thus, the methodology is shifting from qualitative, exploratory to quantitative research methods. **Figure 2** shows the methodological distribution of carbon assurance articles over the review period while **appendix 12**, gives the definitions and categories of research methodologies.

Table 4: *Research methodologies used in carbon assurance research.*

Research methodology	Research methods	Frequency	Percentage (%)
Qualitative methodology	Studies involving cases, studies involving single cases, interviews without a structure, interviews with a semi-structure, observations, an inquiry involving a narration, content, Thematic analysis, literature reviews	12	23
Quantitative methodology	Descriptive, SEM, Linear, Logistic, Multiple, Probit, Logit and Probit, OLS regression, Descriptive statistics, correlation, ANOVA, Chi-square, t-test, Mann- Whitney U test, Experimental design, Generalised method of moments, GLS logit regression, Univariate analysis, Survey design, Tobit model regression	27	52
Mixed methodology	Qualitative methodology: Studies involving cases, data analysis using qualitative methods, interviews with a semi-structure, interviews that are structured and open-ended. Quantitative methodology: Regression, Dephi, Descriptive statistics, Normality tests, Two- stage least squares regression, correlation	1	2
Theoretical and conceptual	Development or testing of theoretical models, Development of models, Conceptual review, technical note, Viewpoint, research note, Descriptive, Non- descriptive studies	12	23
Total		**52**	**100**

Source: Gupta et al. (2020)

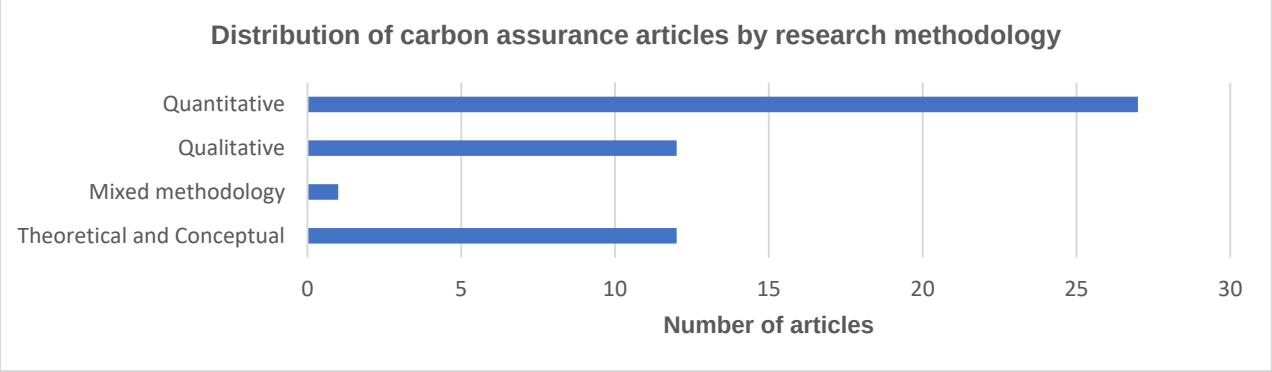

Figure 2: *Review articles by research methodology*

Source: author

The review sample distribution across the continents is illustrated in **Table 5**. Most of the published articles are contextualised into a Multi continental sample (i.e., studies conducted in more than one continent), followed by Oceania, North America and Europe, Asia, Africa, and South America with the least carbon assurance representation. **Figure 3** shows the distribution of carbon assurance articles by continent.

Table 5: *Distribution of review sample by continent*

Continent	Frequency	Percentage (%)
Africa	1	2
Asia	1	2
Europe	5	10
Multi- continental	25	48
North America	5	10
Oceania	15	29
South America	0	0
Total	**52**	**100**

Source: author

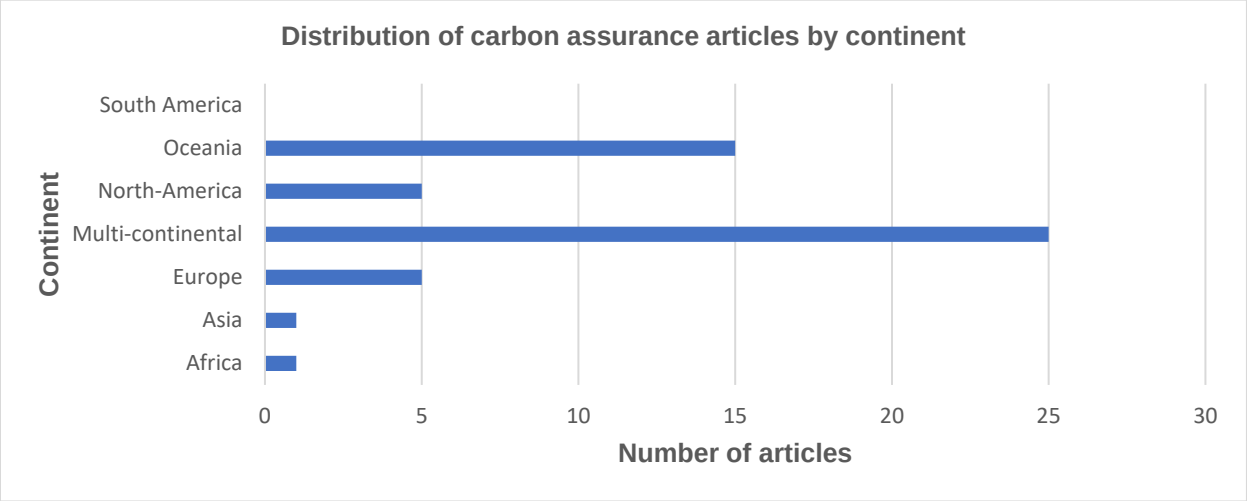

Figure 3: *Distribution of carbon assurance studies across the seven continents.*

Source: author

Table 6 illustrates the journals that publish carbon assurance articles. The 52 articles were published in 24 peer-reviewed academic journals, between the years 2007 to 2023 of which 21 were listed in the Academic Journal Guide; however, 3 Journals (Environment, Journal of Applied Management Accounting Research, and Journal of Asia Pacific Centre for Environment) which published seminal studies were not listed on AJG but included in the review to capture these seminal studies. The accounting journals accounted for 90% of the review articles, with Australian Accounting Review having the highest publications, followed by Sustainability Accounting Management and Policy Journal. Non-accounting journals accounted for only 10% of the publications. **Table 7** shows the distribution of carbon assurance studies by journal category as further illustrated in the **Figure 4.**

Table 6: *Journals publishing carbon assurance research.*

No.	Journal	AJG 2021	ABDC 2022	Field	Frequency	Percentage (%)
1.	The Accounting review	4*	A*	Accounting	2	4
2.	Accounting, Auditing, and Accountability Journal	3	A*	Accounting	3	6
3.	Auditing: A Journal of Practice and Theory	3	A*	Accounting	4	8
4.	The British Accounting Review	3	A*	Accounting	2	4
5.	Journal of Business Ethics	3	A	Ethics	1	2
6.	Accounting Horizon	3	A	Accounting	2	4
7.	Behavioral Research in Accounting	3	A	Accounting	1	2
8.	Business Strategy and the Environment	3	A	Environment	2	4
9.	Critical Perspectives in Accounting	3	A	Accounting	1	2
10.	Journal of International Accounting, Auditing and Taxation	3	B	Accounting	1	2
11.	Accounting Forum	3	B	Accounting	1	2
12.	Accounting and Finance	2	A	Accounting	4	8
13.	International Journal of Auditing	2	A	Accounting	3	6
14.	Journal of International Accounting Research	2	A	Accounting	1	2
15.	Managerial Auditing Journal	2	A	Accounting	1	2
16.	Australian Accounting Review	2	B	Accounting	7	14
17.	Accounting Research Journal	2	B	Accounting	1	2
18.	Current issues in Auditing	2	B	Accounting	3	6
19.	Journal of Applied Accounting Research	2	B	Accounting	3	6
20.	Sustainability Accounting Management and Policy Journal	2	B	Accounting	5	10
21.	Social and environmental accountability Journal	1	B	Accounting	1	2
22.	Environment				1	2
23.	Journal of Applied Management Accounting Research				1	2
24.	Journal of Asia Pacific Centre for Environment				1	2
	Total				**52**	**100**

Source: author

Table 7: *Distribution of review articles by journals*

Journal	Frequency	Percentage (%)
Accounting	46	88
Ethics	1	2
Environment	2	4
Others	3	6
Total	**52**	**100**

Source: author

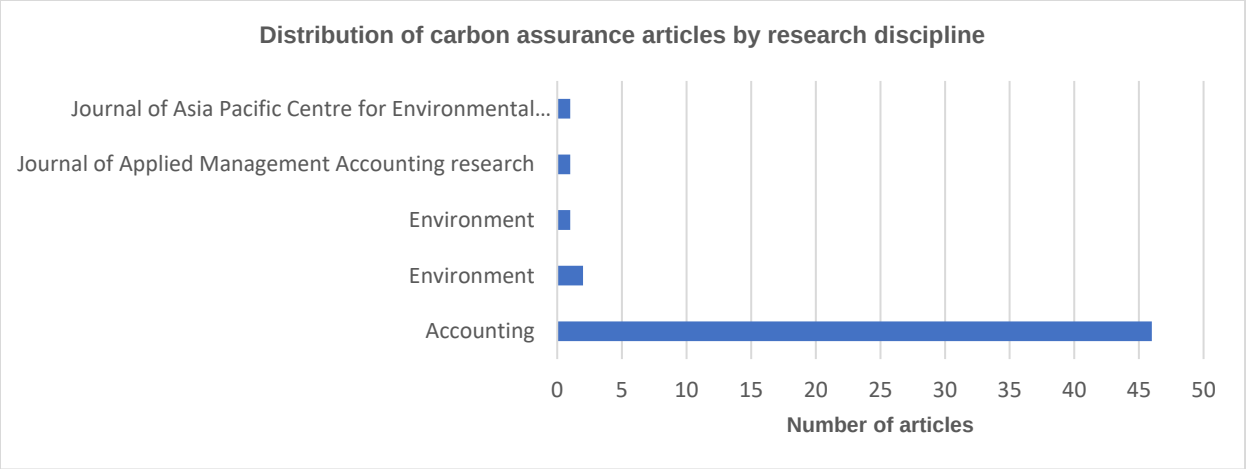

Figure 4: *Distribution of carbon assurance studies by journals.*
Source: author

Overall, the description analysis shows four carbon assurance trends. First, the number of publications has been fluctuating since 2007. Second, in the earlier years, more conceptual papers than empirical were published in journals ranked 1B to 3A*. Later between the years of 2014 to 2016, papers were published in 3A* to 4*A*. After 2016, papers were published in journals ranked 3A* to 2B as shown in **appendix 13.** More empirical papers are now emerging as the market grows, though quantitative exceed qualitative methodologies. The practice is common in several continents, with a higher presence in developed than developing countries. Studies are mainly published in accounting journals and awareness of the construct is aligned with introduction of the greenhouse gas assurance standard and carbon regulation through emission trading schemes.

2.3.2 Inductive content analysis

The review sought to increase our understanding of the approaches applied to carbon assurance, to establish the current themes in literature, theoretical underpinnings, and the gaps in knowledge. To accomplish this, the review adapted an inductive content analysis, a commonly used qualitative approach that systematically identifies, analyses, and draws meaning from textual content data (Cavanagh, 1997; Hsieh & Shannon, 2005; Vaismoradi et al., 2016), by coding and giving account of the themes from the data (Braun & Clarke, 2021; Hsieh & Shannon, 2005; Saunders et al., 2019).

A qualitative approach was chosen because, first, it is best suited for a construct whose literature is developing, and when limited theories exist (Hsieh & Shannon, 2005), hence this suited the carbon assurance context whose literature is emerging, and most topics are still unexplored (Simic et al., 2023). Second, the review questions are exploratory, thus, a qualitative approach,

that inductively derives theory from the data was appropriate, unlike quantitative approaches, that works best with well-developed theory and mature literature. Third, an inductive content analysis approach can best answer the review questions (Braun & Clarke, 2021), by identifying codes in textual data, categorising codes into themes, and interpreting patterns from textual data (Hsieh & Shannon, 2005; King & Brookes, 2018). Fourth, the method is flexible (Cassell & Bishop, 2019; Cavanagh, 1997), and easy to use for a budding scholar like me unlike thematic analysis which is more sophisticated (Braun & Clarke, 2021). Fifth, the approach does not restrict any form of qualitative data (Kenny & Briner, 2010), and theoretical underpinnings (King & Brookes, 2018). Sixth, this method allowed the reviewer to identify theoretical linkages (Cassell & Bishop, 2019).

The reviewer selected the most appropriate approach from a basket of four qualitative data analysis approaches (Braun & Clarke, 2021). Two of which (i.e., content, and thematic analysis) all derive themes from textual data but, use different data analysis methods. For instance, while content analysis requires selecting either an inductive or deductive data analysis approach, thematic analysis in contrast, does not distinguish between these two methodologies (Braun & Clarke, 2021), hence, given the emerging state of carbon assurance literature, and the nature of the review questions, the reviewer selected inductive content analysis.

Other approaches such as, grounded theory, and interpretative phenomenological approach were potentially debated, but not selected, because, although commonly used and involve coding data to inductively derive theory (Braun & Clarke, 2021), the reviewer was not concerned about a phenomenological inquiry of individuals' lived experiences (Hsieh & Shannon, 2005; Saunders et al., 2019), nor was data going to be primarily collected using semi-structured interviews, a common data collection method for this approach (Cassell & Bishop, 2019) but rather, the reviewer was interested in identifying patterns from textual, secondary data.

A 3-step coding and analysis process was adapted from (Gioia et al., 2013; Mosonyi et al., 2020) was followed. In step one, the hard copies of the textual articles were read word by word, while manually coding (Morse & Field, 1995), to develop initial codes for the four earlier identified extraction categories, and reviewer's initial thoughts. Different colour codes and descriptive labels (Hsieh & Shannon, 2005) were used to distinguish the several types of extracted information, although similar codes were assigned to similar categories, to aid further analysis. A constant comparison of data against defined codes was carried out, so that code meaning was maintained during the coding process (Creswell, 2007). To overcome coder bias during manual coding, and to ensure that no new codes emerged (Fusch & Ness, 2015), the reviewer further used Atlas.ti Artificial Intelligence opening coding, to code all the 52 selected articles.

Under step two, atlas.ti codes were transferred to a spreadsheet, to ease movement of codes, categorisation, and formation of themes for credible, replicable review findings (Yin, 2003). Given the need to have a systematic and transparent structured literature review, the reviewer disregarded the notions against counting in qualitative research (Elliot, 2018). The initial coding process thus, generated 191 codes, a number that lies within the recommended range of 50-300 codes (Saldaña, 2016, as cited in Elliot, 2018). The reviewer then regrouped the codes into 19 categories to align with the recommended range of 15-20 categories (Creswell, 2015, as cited in Elliot, 2018) and a number less than the reviewed articles (Gupta et al., 2020). This was done by discarding redundant codes that were not in line with the review questions while using the fill colour feature in excel, to highlight the same colour for similar codes, and different colours for different codes (Hsieh & Shannon, 2005).

In step three, a similarity- difference process was again carried out, to further collapse the 19 categories into 4 themes which later formed the structure on which the literature review was built (Creswell, 2015, as cited in Elliot, 2018; Morse & Field,1995). **Appendix 14** outlines the codes, categories, and emerged themes while **Appendix 15** outlines the code and category definition. I solely cross checked the identified codes more than once, first, to confirm if data was accurately categorised. Second, to ensure that the review was rigorous (Morse, 2015). Third, to ensure that there was no discrepancy concerning assigned codes (Creswell, 2007), and fourth, to ensure no new codes could emerge from the data (Brod et al., 2009). The findings were reported and synthesised using a narrative, interpretative approach because, first, it is one of the least used synthesis methods in systematic literature reviews, despite its importance in providing deep theoretical understanding of review findings (Rojon et al., 2021), second, it minimises the weaknesses of a single primary study, and improves internal and external validity (Rousseau et al., 2008). Findings were visually represented in the form of tables, graphs, and charts.

2.3.3 Data quality strategies

The following strategies were implemented to have a rigorous and good quality structured literature review.

a) Search process and sample size

The reviewer extended the review period to cover the years 2007 to 2023, to minimise having a thin dataset (Snyder, 2019), and to aid data analysis and saturation (Morse, 2015). The formative state of carbon assurance literature could not allow a restriction on the review period least I compromised the quality of the review because, of the limited literature on the construct (Datt et

al., 2018). The reviewer greatly detailed the search, data abstraction, analysis, and reporting processes, to audit trail and increase the review rigor (Tranfield et al., 2003).

b) Data coding

The reviewer coded the data twice both manually and using a computer aided qualitative data analysis software (i.e., atlas.ti). This was carried out to aid comparison of codes between the two coding methods. Second, to ensure that the codes identified manually were reliable and consistent (Elliot, 2018) with those identified by atlas.ti. I engaged with the data more than once to ensure that codes were accurately identified (Elliott, 2018; Hsieh & Shannon, 2005) and categorised for a rigorous review (Morse, 2015). Second, to ensure no inconsistencies were visible when assigning codes (Creswell, 2007).

The reviewer used a code book which included code definitions (Braun & Clarke, 2021) as shown in **appendix 14 and 15,** to record the identified codes, categories, and themes for a reliable (Schreier, 2012), credible, and valid review. Second, to ensure that the manually identified codes were similar to those identified by atlas.ti . Third, to ensure that the meaning of the codes did not change (Creswell, 2007) while coding with atlas.ti. Fourth, to ensure transparency (Chenail, 2012) in coding and to provide an audit trail of the codes, categories, and themes.

2.3.4 Limitations

Good science should be replicable, transparent (Battacherjee, 2012), and so should a structured literature review (Snyder, 2019). A structured literature review particularly, an inductive content analysis approach that is coder reliable, draws on a coding framework (Braun & Clarke, 2021), and uses many coders to identify codes, categories, and patterns from the data was adopted. This review was, however, single handedly written, although under a supervisor's guidance, hence, the reviewer subjectively, and solely coded, abstracted themes from the data, analysed, and interpreted the findings. This may, hence, compromise the findings because, this was a one individual project that did not benefit from peer reviews (Cutri et al., 2021; Gupta et al., 2020), and inter coder reliability to validate the degree of coding accuracy. Nonetheless, to increase reliability and transparency, the reviewer engaged with the data for prolonged periods of time (Hsieh & Shannon, 2005), and code definitions were included in the coding framework (Braun & Clarke, 2021) as shown in **Appendix 16**.

The reviewer also dedicated a substantial amount of time detailing the process, and steps undertaken in the search, data abstraction, analysis, and reporting of findings. All justifications and decisions undertaken (Tranfield et al., 2003) have been well documented in the report. A

structured literature review is a very systematic process, whose nature requires collaboration of several reviewers, to guarantee good quality and replicable findings (Tranfield et al., 2003). Mindful of the single effort put into this project the reviewer, did not however, make attempts to minimise the subjective inclusion and exclusion of articles, by involving at least two reviewers to decide on the most relevant articles to include or exclude. Further still, there was absence of assessors in the data extraction stage (Tranfield et al., 2003), hence, there may be errors in the abstraction of data which could impact on study findings.

Identification of the review sample was difficult because the conceptualisation of carbon assurance is not thoroughly discussed in literature. Carbon assurance is defined “an examination conducted by a third party (auditor) of GHG emissions (including of CO2) for an organization responsible for the subject matter in order to enhance the degree of confidence of the users of a GHG statement” (Tang, 2019, p.377), while others, define it as “a response to perceived legitimacy threats arising from more stringent carbon legislation and growing public awareness” (Datt et al., 2019, p.195). As earlier identified in the search strategy, “carbon assurance”, “greenhouse gas assurance”, “carbon audit” keywords, among others were used to identify the articles. Articles that discussed the broader sustainability assurance concepts were discarded, because, of the differences in subject matter. While greenhouse gas emissions are the focus of carbon assurance, environmental and social issues shape assurance of sustainability information (Datt et al., 2020).

Given the vagueness of the carbon assurance definition, and the inexhaustive formation of search strings (Rojon et al., 2021), it is possible that some relevant articles were not considered in the review. The thematic structure and conclusions made in the review were drawn from highly cited papers, published in high quality journals, and whose methodology was structurally sound to produce convincing results (Petticrew, 2001). Although 52 articles were selected for the review, the papers were further critically appraised, to assess the credibility of study methods and findings, thus, papers that had low citations, except for the recent publications and whose methodology was not aligned with the review questions (Tranfield et al., 2003), were only included in the review’s descriptive analysis and not the main thematic structure, to ensure a good quality structured literature review. In summary, 52 carbon assurance articles were selected using an inclusion criterion. Findings from the abstraction and analysis of data show that the research field is emerging, evidenced from the fluctuating trend in publications. An inductive content analysis and coding structure produced several themes on which the following chapter is built.

Chapter 3: Structured Literature Review

3.1 Introduction

Carbon assurance is rarely defined in literature and when defined, it is by a few scholars. Nonetheless, the construct means different things to different scholars, seen by the variations in names. As such, there is no integration of the definition of carbon assurance. Carbon assurance approaches are another gem yet to be discovered. Literature places great emphasis on the antecedents and challenges of greenhouse gas statement assurance, the first approach of carbon assurance, but less on the process and outcomes, despite the existence of three distinct other approaches minimally introduced by one scholar. Lastly our understanding of the theorisation of carbon assurance is still limited, as diverse and sometimes similar theories are used to explain the phenomenon. The following is the elaboration of these arguments.

3.2 Definition of carbon assurance

The definition of carbon assurance has received less elaboration since the conception of the construct. This is evidenced by the few definitions that exist in the reviewed literature. **Table 8** outlines the different definitions used by scholars to understand carbon assurance over the period. Notable variations are seen in the prerequisite factors necessary for conducting carbon assurance, among which are the antecedents, process, assurance provider, subject matter, and end users of the assured greenhouse gas statements.

Table 8: *Carbon assurance definitions*

Author	Carbon assurance definition
Datt et al. (2018)	"Carbon assurance is one dimension of sustainability assurance" (p.3)
Datt et al. (2019)	"Carbon assurance is a response to perceived legitimacy threat arising from more stringent carbon legislation and growing public awareness" (p.195)
Tang (2019)	"Carbon auditing is an examination conducted by a third party (auditor) of GHG emissions (including of CO2) for an organisation responsible for the subject matter in order to enhance the degree of confidence of the users of a GHG statement" (p.377)
Datt et al. (2020)	"Carbon assurance is an extension of sustainability assurance" (p.146)

Source: author

The first definition by Datt et al. (2018, p.3) is like Datt et al. (2020, p.146) given that they both refer to carbon assurance as “an extension of sustainability assurance.” The second definition by Datt et al. (2019, p.195) differs from the two previously mentioned definitions by including only the antecedents of carbon assurance. These include threats to legitimacy, legislation of emissions, and awareness of the public. Lastly, the definition by Tang (2019, p.377) resembles that of Datt et al. (2019) in that the former, includes enhancing confidence of end users as an antecedent, however, the difference rests on the process, the auditor, the subject matter, the beneficiary, and the end users.

In sum, this review defines carbon assurance as third- party inspection conducted for an organisation responding to legitimacy, carbon legislation, and public concerns, to enhance the confidence of greenhouse gas emissions statement users”.

3.3 Carbon assurance approaches

Literature demonstrates four approaches of carbon assurance, that are diverse, in terms of, the definition, purpose, scope, nature, users of assured statements, antecedents, process, outcomes, and challenges as shown in **Table 9**. Green and Zhou (2013) confirms the diversity of carbon assurance practices.

Carbon assurance approaches include first, the Greenhouse gas statement assurance, the most studied approach in literature, which verifies greenhouse gas and energy emissions (Martinov-Bennie & Hoffman, 2012; Tang, 2019). Second, compliance carbon audit, that determines whether a firm and project’s carbon emissions or activities, are in line with the set carbon emission regulation. Third, carbon management audit, that determines the cost effectiveness of a project or organisation’s carbon management and internal control measures. Lastly, governmental climate change audit, that evaluates the effectiveness of a nation’s climate policy (Tang, 2019).

The review will consider these approaches in that order, while uniquely differentiating them in terms of the definition, purpose, scope, nature, users of assured statements, antecedents, process, outcomes, and limitations.

Table 9: *Distinguishing attributes of carbon assurance approaches*

Carbon assurance approach	Greenhouse gas statement assurance	Compliance carbon audit	Carbon management audit	Governmental climate change audit
Definition	×	×	×	×
Purpose	True and fair presentation of greenhouse gas emissions	Determines compliance with regulation	Determines effectiveness of carbon management	Determines appropriateness of governmental climate change policy
Scope	Firm	Firm and project	Firm and project	National / International
Nature	Verification	Investigative	Evaluative	Evaluative
Users	External	External/ Managers	Managers	Government/Public
Antecedents	✓	✓	✓	✓
Process	×	×	×	×
Outcomes	✓	×	×	×
Challenges	✓	×	✓	×

Source: Tang, 2019

The review also revealed several geographically contextualised carbon assurance names to allude to either, assurance of greenhouse gas statement, carbon audit compliance, audit of carbon management, and audit of governmental climate change. **Table 10** outlines the commonly used names, the country in which the names are used, as well as the aligned carbon assurance approach as discussed in literature.

Table 10: *Carbon assurance names, and approaches per country*

Country	Greenhouse gas statement assurance	All carbon assurance approaches
Australia	Greenhouse gas emissions assurance	
China		Carbon auditing, climate change auditing
Other International countries	Greenhouse gas (GHG) Information Assurance, (GHG) emissions assurance, greenhouse gas assurance, GHG assurance, assurance of greenhouse gas emissions disclosures, independent carbon assurance, independent assurance of greenhouse gas statements, assurance on carbon emission disclosures	
United Kingdom	Carbon assurance	
United States of America	External carbon assurance, externally assuring carbon emissions reports.	

Source: author

Table 10 above illustrates the variety of names used for greenhouse gas assurance in contrast to other carbon assurance approaches. In the United Kingdom for instance, greenhouse gas statement assurance is commonly referred to as carbon assurance, while in the USA and other international countries, a wide assortment of names such as greenhouse gas (GHG) information assurance, (GHG) assurance, external carbon assurance, are used to refer to greenhouse gas statement assurance. In contrast, carbon auditing or climate change auditing is commonly used to refer to all approaches of carbon assurance in China.

In sum, carbon assurance approaches names vary per country, thus, for clarity, this review adopts carbon assurance, carbon auditing, external carbon assurance, greenhouse gas assurance, and carbon emissions assurance, to refer to the four approaches of carbon assurance. Similarities and differences between the four approaches of carbon assurance (i.e., Greenhouse gas statement assurance, compliance carbon, carbon management, and governmental climate change audit) emerged while reviewing the literature, to have an orderly review, the reviewer first discusses each approach independently, while uniquely differentiating them in terms of the definition, purpose, scope, nature, users of assured statements, antecedents, process, outcomes, and challenges, then subsequently provides the emerging themes from the approaches, and theoretical underpinnings used in literature, in a holistic way.

3.3.1 Greenhouse gas statement assurance

a) Definition, purpose, scope, nature, and users

Few scholars explicitly define greenhouse gas statement assurance. The approach is instead described as a relatively new type of assurance engagement on public, non -financial information, besides sustainability assurance (Zhou et al., 2016). Tang and Luo (2014) similarly view it as an element of carbon management system. In terms of subject matter, scholars (Datt et al., 2019; Martinov-Bennie & Hoffman, 2012) agree that greenhouse gas statement assurance, focusses on greenhouse gas emissions, unlike sustainability assurance, that focusses on environmental and social matters (Zhou et al., 2016). Assurance of greenhouse gas statement verifies the fairness of greenhouse gas emissions (Tang, 2019) to ascertain the quality of disclosed information (Simnett et al., 2009). Firm level is the assurance scope while verification is the nature of assurance, and the external users are the only end users of the assured report (Tang, 2019).

b) Antecedents of Greenhouse gas statement assurance

The literature discusses both internal and external antecedents for the adoption of Greenhouse gas statement assurance (Zhou et al., 2016). Climate change is one of the common external motivators for assuring greenhouse gas statements attributed to global warming (Luo et al., 2023), and triggered by man's activities (Datt et al., 2018). Increasing pressure from stakeholders (Mateo-Márquez et al., 2020; Tang, 2019) has thus, driven firms shift to new corporate carbon accounting practices, such as carbon assurance, to reduce carbon footprint (Tang & Demeritt, 2018).

Internally, voluntary reporting of carbon emissions drives adoption of assurance because of managerial motivations to greenwash performance of carbon emissions (Datt et al., 2019). Carbon assurance, hence, creates a need to improve accuracy of the disclosed carbon emissions information (Dutta, P. & Dutta, A., 2021).

High exposure to carbon risk, is another internal driver of greenhouse gas assurance. In such cases, assuring greenhouse gas emissions, helps to offset public scrutiny (Datt et al., 2018, 2019), and legitimacy threats (Rohani et al., 2023) concerning the high emitted carbon emissions.

c) Greenhouse gas statement assurance process

Little is mentioned about the greenhouse gas assurance process in literature. Green and Taylor (2013) confirm that, much focus is put on the consequences of assurance of greenhouse gas engagements compared to the process. Nonetheless, the assurance process is described as

complex (Datt et al., 2020; Green & Li, 2012; Knechel, 2021) because it involves a scientific quantification and estimation of emissions data (Green & Li, 2012).

Rohani et al. (2023) notes that two parties, namely, reporting firms, and assurors are the main parties to the assurance process. Martinov-Bennie and Hoffman (2012), Knechel (2021), and Rohani et al. agree that the process involves, evidence gathering, assessment of the accuracy of subject matter, evaluation of internal controls, as well as discovery of errors in subject matter information.

d) Outcomes of Greenhouse gas statement assurance

Greenhouse gas assurance improves the quality of reporting (Luo et al., 2023). This is the case because greenhouse gas assurance minimises managers' incentives of engaging in earnings management, which conflicts with other stakeholders' interests (Bui et al., 2021) by ensuring that all stakeholder needs are fully met.

Greenhouse gas assurance positively, and significantly improves the credibility (Green & Li, 2012; Tang & Demeritt, 2018) of climate change (Dutta, P. & Dutta, A., 2021), carbon (Luo et al., 2023), environmental (Moroney et al., 2012), and greenhouse gas emissions (Mahmoudian et al., 2023) disclosures. This is the case because external assurance acts as a monitoring tool, through which managers' incentive to manipulate climate-change information is minimised (Dutta, P. & Dutta, A., 2021) to improve disclosed greenhouse gas emissions quality (Mahmoudian et al., 2023).

External assurance of greenhouse gas emissions increases firm value (Astuti et al., 2023; Mahmoudian et al., 2023) by lowering debt costs eventually encouraging more investment in projects that reduce carbon emissions (Mahmoudian et al., 2023).

e) Challenges of Greenhouse gas statement assurance

a. Diversity and lack of assurance regulation

Scholars (Datt et al., 2019; Fan et al., 2021; Green & Taylor, 2013; Ioannou et al., 2016; Ratnatunga, 2007) agree that diversity and lack of assurance regulations, is one of the most influential challenges that affect the assurance of greenhouse gas statements. One way of interpreting diversity is that assurors use different assurance standards, for instance accounting firms, can either use ISAE 3410 or ISAE 3000 standard, for greenhouse gas emissions assurance, and the broader sustainability subject matters, while specialist firms like engineers and scientists, may use 1SO 14064-3:2006 (Kazemian et al., 2022), but may additionally use standards used by accounting firms (Green & Zhou, 2013). This diversity makes comparison of disclosures (Mia et al., 2019), and benchmarking difficult (Ioannou et al., 2016).

b. Practical implementation of greenhouse gas emissions assurance process

The understanding of how the assurance standards and process are practically implemented is not yet known (Datt et al., 2018). Moreover, the credibility of the assurance process is also questionable on grounds of managerial influence, and limited level of assurance provided (Comyns & Figge, 2015).

c. Choice of Greenhouse gas emissions assurance providers

The market for greenhouse gas emissions is indecisive about who should assure greenhouse gas emissions. This is attributed to, first, the diversity in assuror skills. Scholars (Chatterjee, 2012; Rohani et al., 2023) concur that, while accounting firms have expertise in auditing, specialist consultants, on the other hand, have specific subject matter knowledge, vital for the technical assurance of greenhouse gas emissions (Chatterjee, 2012; Rohani et al., 2023). Second, reporting firms, must choose between accounting firms that have high reputation, offer higher quality assurance, given the transferability of financial auditing concepts to greenhouse gas auditing, and specialist firms, whose quality checks are less rigorous than accountants, although offer cheaper services than accountants (Huggins et al., 2011). Third, the difference in expertise further means that, different assurance providers employ different approaches, and methodologies (Chatterjee, 2012; Fan et al., 2021). In sum, the right blend of assurance and technical skills is necessary (Green et al., 2009) and working in multi-disciplinary teams (MDT) is thus, unavoidable.

d. Greenhouse gas emissions assurance skills

The specific knowledge, and expertise required in the greenhouse gas emissions assurance process remain unknown (Datt et al., 2018), and yet the process is described as technical, complex (Knechel, 2021; Trotman & Trotman, 2015). New practices like carbon assurance, although Olson (2010) oppose its newness, while Xu and Andrew (2021) in comparison assert that the term “new” may refer to the realignment of competencies, nevertheless require an integration of new and unique skillsets (Chithambo & Taurigana, 2014; Huggins et al., 2011, Knechel, 2021; Tang, 2019) to increase stakeholder confidence in assured carbon disclosures (Datt et al., 2018).

3.3.2 Compliance carbon audit

a) Definition, purpose, scope, nature, and users

Few scholars define compliance carbon audit like greenhouse gas emissions assurance, nonetheless, it is a qualitative evaluation to ascertain whether firm's activities are in conformity with the stipulated climate-change laws (Tang, 2019). Compliance carbon audit has three mentioned aims in literature. First, to test whether a firm's activities, comply with the set regulations (Green & Zhou, 2013). Second, to determine the quantity of carbon emitted. Lastly, to scrutinise the environmental effect of a firm's activities (Tang, 2019). Firm and project are the scope for this assurance engagement while the nature of assurance is investigative, and external users and internal firm managers are the end users of the assured carbon compliance report (Tang, 2019).

b) Antecedents of compliance carbon audit

Emergence of carbon regulation and government investment in low carbon projects are cited in literature as the external antecedents for the adoption of compliance carbon audit (Tang, 2019).

3.3.3 Carbon management audit

a) Definition, purpose, Scope, nature, and users

The definition of carbon management audit is non- existent in literature. Nonetheless, carbon management audit determines whether a project and organisation's carbon management and controls are cost effective, efficient, and achieve the intended purpose of mitigating carbon emissions (Tang, 2019). The scope is project and firm level, while the assurance is evaluative in nature and involves assessing the efficiency of a firm's carbon management system, lastly, internal managers are the targeted end users of the report (Tang, 2019).

b) Antecedents of carbon management audit

Emergence of carbon regulation and government investment in low carbon projects are cited in literature as the external antecedents for the adoption of carbon management audit (Tang, 2019).

c) Challenges of carbon management audit

a. Reluctance to adopt carbon management practices.

There is consensus in literature that slow uptake of carbon management audit is attributed to the reluctance of adopting carbon management practices (Kazemian et al., 2022; Tang & Luo, 2014). Evidence provided in literature mentions that only 10% of high emitting Australian firms, considered reporting their carbon management due to uncertainties surrounding the practice of carbon management (Kazemian et al., 2022).

b. Lack of carbon management assurance standard

The absence of a carbon management assurance standard affects carbon management audit because there is no guidance on both carbon management reporting and assurance. Although carbon management audit evaluates the cost effectiveness of a project or organisation's carbon management and internal controls, the discussion about carbon management audit is non-existent in literature, probably attributed to the slow adoption of the practice, confirmed by noting that only 39% of high emitting Australian firms appoint assurors to audit their carbon management reports. Additionally, carbon management accounting practices are new, evidenced by their absence in Australia (Kazemian et al., 2022) and yet Australia was among the first countries to introduce mandatory assurance of greenhouse gas statements. Moreover, carbon management accounting practices vary according to the firm and sector (Kazemian et al., 2022), which probably explains why our understanding of carbon management assurance practices remain unexplored.

3.3.4 Governmental climate change audit

a) Definition, purpose, scope, nature, and users

Governmental climate change audit is not explicitly defined like the rest of the four carbon assurance approaches, nevertheless, this kind of carbon assurance involves evaluating whether a nation's climate policy is effective in achieving the set climate change targets. It may also involve; evaluating how climate change mitigation funds are being utilised, assessing how a climate change policy is institutionalised, implemented, as well as its consequences (Tang, 2019). The scope of assurance engagement is either national, or international and this assurance is evaluative in nature, while public and governmental officials are the end users of the assured report (Tang, 2019).

a. Antecedents of Governmental climate change audit

Emergence of carbon regulation and government investment in low carbon projects are cited in literature as the external antecedents for the adoption of Governmental climate change audit (Tang, 2019). To crown it all, carbon assurance has four approaches distinct in purpose, scope, nature of assurance, and end users of assured report. The review notes that three approaches, namely, carbon audit compliance, audit of governmental climate- change, and audit of carbon management, are minimally discussed in literature in terms of the definition, antecedents, audit process, outcomes, and challenges compared to greenhouse gas statement assurance.

3.4 Emerging themes in carbon assurance

3.4.1 Emerging themes on antecedents

Literature demonstrates that demand for carbon assurance is influenced by both external and internal drivers (He et al., 2022; Zhou et al., 2016) because assurance practices are diverse (Green & Zhou, 2013) as shown in **Appendix 17**. The review of the antecedents will consider these levels in that order.

A. External drivers of carbon assurance

a) Climate change pressures

Scholars (Huggins et al., 2011; Pitrakkos & Maroun, 2018) agree that climate change is the most influential motivator for the adoption of carbon assurance. This is so because, climate-change is caused by global warming arising from greenhouse gas emissions (Ascui, 2014; Dutta, P. & Dutta, A., 2021; Luo et al., 2023), which are triggered by man (Ratnatunga, 2007) and firm activities (Datt et al., 2018) particularly, high emitting ones (Simnett et al., 2009).

Increasing stakeholders' pressure and public awareness about climate change (Bui et al., 2021; Mateo-Márquez et al., 2020) have thus, driven firms to incorporate this externality into internal business processes (He et al., 2022), causing shifts from the traditional accounting practices such as, financial audit, to new corporate carbon accounting practices, such as carbon assurance, to signal to stakeholders, firms' responsiveness to reduce carbon footprint (Chithambo & Taurigana, 2014; Tang & Demeritt, 2018). Comyns (2018) confirms that multinational organisations, subjected to different institutional, climate change pressures subsequently adopt practices to minimise such pressures.

Besides firms, governments (Datt et al., 2019; Green & Li, 2012; Tang, 2019), and cities (Mia et al., 2019), are also under immense pressure, to reduce carbon emissions. In China for instance, the high pollution related death rates, have influenced the Chinese government to implement carbon reduction projects (Tang, 2019). In sum, demand for carbon assurance increases as climate change threats increase and consequently escalate the demand for credible greenhouse gas information by several stakeholders. This information is vital to assess potential risks on business and survival (Datt et al., 2018; 2020), as well as the causes and strategies of reducing carbon emissions (Busch et al., 2023). Carbon assurance in such cases, enhances the credibility of information by monitoring managers' incentive to greenwash carbon performance (Datt et al., 2020; Dutta, P. & Dutta, A., 2021; Fan et al., 2021; Tang, 2019), but also transitions firms and countries to a low carbon economy (Tang, 2019).

b) Carbon regulation pressures

Governments should enact and enforce laws to safeguard the interests of the public (Comyns, 2018; Martinov-Bennie & Hoffman, 2012; Martinov-Bennie, 2012) as such, governments regulate the pricing, and consumption of energy (Simnett et al., 2009; Tang & Luo, 2014) to ensure that it is available for the generations to come. Firms are thus, obliged to operate within the set country regulations, least they face consequences for non- compliance especially for activities deemed harmful to society (Martinov-Bennie & Hoffman, 2012).

Carbon institutions, as carbon regulating bodies, are manifested in two forms in literature, namely, government regulatory policy programs and carbon reduction targets (Tang, 2019). The emphasis placed on climate change and global warming defers by country (Olson, 2010), and as such, these variations consequently, influence firms' actions and goals towards addressing the different needs of the various stakeholders (Zhou et al., 2016) for instance, firms in China, are expected to operate within the set energy consumption laws to mitigate carbon emissions given that they are considered one of the greatest causes of climate change (Tang, 2019).

Besides climate change pressures, regulatory pressures also drive disclosure and assurance of information (Mateo-Márquez et al., 2020). Open trade policies, strong legal frameworks (Chatterjee, 2012; Mateo-Márquez et al., 2020), ecological protection systems (Datt et al., 2018), emissions trading and emissions reporting schemes such as, EU ETS (Zhou et al., 2016), drive carbon assurance to alleviate regulatory external pressures, and reduce climate change (Bui et al., 2021; He et al., 2022). In sum, regulations drive firms' actions towards engagements that safeguard society (Chatterjee, 2012; Zhou et al., 2016), however, in the absence of strict regulation, carbon assurance can substitute for such deficiencies (Luo et al., 2023).

c) Industry pressures

There are mixed results in literature surrounding industrial factors as drivers of carbon assurance. While some (Fan et al., 2021; Green & Zhou, 2013) assert that International and European firms in high carbon impact industries respectively, purchase the services of an external assurance provider, more recent findings, however, note that international firms operating in sectors with less carbon activity, assure their greenhouse gas statements (Luo et al., 2023). In comparison with Luo et al. but in contrast with Fan et al. and Green and Zhou, Simic et al. (2023) notes that, firms in high carbon impact industries, with compensation controversies, are unlikely to assure. Moreover, international firms from the materials, energy, utilities, capital goods, banks, and food

beverage and tobacco, are identified as the top five industries, that assure their greenhouse gas emissions disclosures (Green & Zhou, 2013). Similarly, electricity, transport, and agriculture are among Australia's high emitting carbon industries (Kazemian et al., 2022). Literature would benefit from an understanding of why international firms in low carbon impact sectors, assure their carbon disclosures.

d) Stakeholder orientation

A country's business culture drives the adoption of carbon assurance. Two types of business culture are mentioned in the carbon assurance literature, namely, stakeholder-orientation, and shareholder-orientation. A stakeholder-oriented country is one that; emphasises maximization of stakeholders' benefits, and good environmental performance, over earnings performance, while shareholder-oriented countries focus on maximising the profits available to a company's shareholders (Chatterjee, 2012; Luo et al., 2023).

Stakeholders influence decisions to assure carbon emissions (Huggin et al., 2011), hence, firms operating in countries with stakeholder orientation seek carbon assurance while the reverse is true for those in shareholder-led countries (Chatterjee, 2012; Luo et al., 2023; Zhou et al., 2016), because, first, a firm's quest for long-term survival drives management, to align company interests with those of the stakeholders, moreover, the influence is stronger for firms with stronger corporate governance attributes (Chatterjee, 2012; Zhou et al., 2016). Second, the need to validate the disclosed carbon emission information (Luo et al., 2023) also drives the adoption.

Besides the influence to purchase assurance of carbon emissions, stakeholder orientation also influences the choice of assuror. High emitting firms in countries with stakeholder orientation purchase carbon assurance from professional accountants than specialists (Datt et al., 2020).

f) Government investment in low carbon projects

Governments all over the world are heeding to change calls for communal engagement in mitigating climate change, as such, they have set up energy conservation, carbon reduction initiatives, and are providing funding, to encourage investment in innovative low carbon projects. Although firms are one of the beneficiaries of such projects, they may however, be propelled to divert resources meant for carbon reduction projects into other pressing projects. Carbon audit in this case, serves two purposes, first, it acts as a monitoring tool, that investigates, how well firms utilise government resources, in the drive to achieve a net-zero economy. The auditor's opinion about green project execution is thus, crucial to the improvement of future carbon reduction projects, and laws governing resource use. Second, carbon assurance increases investors'

confidence (Ioannou et al., 2016; Vera-Muñoz et al., 2020), which further improves the chances of firms receiving future green funding. Increase in government investment in low carbon projects in China is partially attributed to the institutionalisation of carbon institutions (Tang, 2019).

B. Internal drivers for the adoption of carbon assurance

a) Carbon risk exposure

High exposure to carbon risk increases stakeholder pressure (Datt et al., 2020) and drives high emitting firms (Datt et al., 2018, 2019), characterised by higher levels of carbon emissions (Datt et al., 2019) to disclose and assure their carbon emissions, to offset high stakeholder public scrutiny (Datt et al., 2018, 2019; Olson, 2010), regulatory legitimacy threats (Datt et al., 2018, 2019, 2020; Rohani et al., 2023), of which professional accountants are most suitable for this role than specialist firms (Datt et al., 2020).

b) Carbon emissions disclosures

Of what use is carbon assurance without carbon disclosure? Green and Zhou (2013) clearly note that, carbon emissions disclosures are inputs to any carbon emissions initiative, hence fundamental to reducing carbon emissions, however, the voluntary nature of carbon emissions disclosures, create reliability concerns, which are settled through carbon assurance (Olson, 2010). Carbon disclosure is among the commonly categorised driver of carbon assurance.

Two forms of carbon emissions disclosures are identified in literature. First, the mandatory disclosures, that require reporting and assurance in line with the stipulated, regulatory, disclosure requirements (Huggins et al., 2011), examples include, EU ETS (Green & Zhou, 2013; Zhou et al., 2016), Alberta-based Greenhouse gas reduction program (Zhou et al., 2016), Australian's NGERS (Lodhia & Martin, 2012), United States of America State of New Mexico mandatory greenhouse gas reporting requirements (Green & Zhou, 2013; Simnett et al., 2009). Second, voluntary disclosures, where firms discretionary report their carbon performance, examples mentioned in literature include the carbon disclosure project (Mateo-Márquez et al., 2020), United States of America City of California Climate Action Registry, and lastly, firms can report in sustainability reports, stand-alone greenhouse gas emissions statements, or in a company's annual reports (Green & Zhou, 2013; Rohani et al., 2023; Trotman & Trotman, 2015; Zhou et al., 2016).

Literature notes an increase in greenhouse gas emissions disclosure (Green & Zhou, 2013), however, these disclosures are questionable because, of their voluntary nature, lack of uniform assurance standard, and managers' incentives to greenwash carbon performance (Datt et al.,

2019), hence, such discrepancies, create a need for carbon assurance, for instance, Green and Zhou (2013) note carbon disclosures between the year 2006 to the year 2008 increased. In sum, carbon disclosure drives the need to improve accuracy of the disclosed carbon emissions information.

c) Carbon governance mechanisms

A good carbon governance structure drives carbon assurance adoption. It is the duty of the board and management, to ensure that all stakeholders' needs are met in the most cost-effective way, thus, to accomplish this, managers are tasked with utilising firm resources, to achieve the diverse needs of stakeholders. Additionally, managers are obliged to involve all stakeholders, by communicating financial and environmental performance, hence disclosing, and assuring of financial and environmental information acts as a communication mechanism, to ensure that stakeholders are constantly aware of management's actions, to guarantee their long-term collaboration with stakeholders (Datt et al., 2018). The following are the four corporate governance mechanisms drivers of carbon assurance.

a. Environmental committee

Presence of an environmental committee may act as evidence to external stakeholders, that a firm is heeding to sustainability calls by integrating climate- change initiatives into its normal business operations. Boards, as custodians of such initiatives, are responsible for resource allocation decisions, towards climate change mitigating projects. More so, the board should constantly involve company stakeholders in such drives. Disclosure and assurance of carbon emissions, hence, becomes inevitable in such circumstances (Datt et al., 2018), thus, in sum, environmental committees drive assurance of carbon emissions.

b. Compensation and carbon reduction incentives

Favorable compensation (Simic et al., 2023) and incentive packages (Datt et al., 2018; Ioannou et al., 2016), motivate management, firm workers to get engaged in carbon reduction initiatives (Datt et al., 2018) to reduce carbon footprint (Ioannou et al., 2016). The incentive and compensation packages should, however, be well aligned with a company's and individual's set carbon reduction targets (Datt et al., 2018), to alleviate the negative consequences of compensation controversies which arise from awarding employees, managers, and executives' higher compensations in the absence of good carbon performance (Simic et al., 2023).

In essence, firms that link sustainability incentives, to executive compensation packages, assure their carbon emissions disclosures to increase the reliability of disclosed carbon information,

because higher compensation packages, prompt executives to disclose only good carbon performance, which weakens the very essence of carbon disclosure. Carbon assurance, hence, enhances credibility where managers are tempted to green wash carbon performance (Tang & Demeritt, 2018) with the hope of getting higher remuneration and incentives. Moreover, since the reward of carbon reduction incentives is dependent on proper quantification and verification of reduced carbon footprint, the role of an assuror, hence, becomes inevitable (Datt et al., 2018).

Additionally, firms located in countries with strong, legal frameworks, like in the United Kingdom, will have an incentive to assure, to improve credibility of disclosed emission information, since disclosure of carbon emissions (Datt et al., 2019) and executive compensation (Simic et al., 2023) is mandatory.

c. Carbon transparency

The quest for transparency, is one of the most influential drivers of assurance of carbon emissions information. Carbon emission information, transcends greenhouse gas emissions, and includes, although not limited to, a firm's carbon accounting, assurance, and management mechanisms, carbon reduction initiatives, carbon opportunities and risks, hence, firms that desire to increase stakeholder trust in the disclosed information (Datt et al., 2018, 2019; Vera-Muñoz et al., 2020) and higher carbon performance transparency will be driven to disclose carbon emissions.

d. Proactivity and carbon reduction activity

Climate change proactive firms engage in carbon reduction activities such as, low- carbon innovations and projects (He et al., 2022; Ioannou et al., 2016), to improve operation processes (Datt et al., 2018) and signal firm responsiveness to social and environmental concerns (Luo et al., 2023). Such proactive firms usually outcompete their peers in performance of carbon emissions and assure carbon disclosures to improve the credibility to reported carbon reduction activities. In sum carbon assurance works best with an already existing carbon governance mechanism (Datt et al., 2018).

d) Carbon information asymmetry

This is a situation where managers are more knowledgeable about a company's carbon performance than external stakeholders (Dutta, P. & Dutta, A., 2021). These information gaps, hence, create a need for carbon assurance to monitor the actions of internal management to reduce tendencies to conceal bad performance since voluntary carbon disclosure is ineffective at minimising information asymmetry (Fan et al., 2021). Carbon assurance thus, improves the quality of disclosed information (Comyns & Figge, 2015). This coincides with Luo et al. (2023) who note

that, carbon assurance reduces managers' incentives to engage in activities beneficial to them, but detrimental to the firm stakeholders. In support of Fan et al. and Luo et al. Pitrakkos & Maroun (2018) note that carbon disclosures are only able to diminish information asymmetry, only when the disclosed information is of good quality. In contrast, however, earlier findings reveal that, assuring carbon disclosures may not minimise information gaps, because it may conceal poor performance of emissions (Datt et al., 2018).

Nonetheless, three forms of carbon information gaps exist. First, quantity of carbon emissions, where large and high emitting firms, assure carbon disclosures, because their operations are presumed to have a higher carbon footprint than small firms (Fan et al., 2021). Second, a firm's complex energy structure, drives the need for assurance of greenhouse gas emissions. Firms use various sources of energy such as, coal, electricity, gas thus, the broader the variation in energy sources, the more complex it is to measure, record, analyse, interpret, and report the carbon emissions. Moreover, the complicated carbon accounting systems firm use, makes tracking of carbon performance, by external stakeholders difficult, hence increasing the carbon information asymmetry. Third, firms in high carbon emitting sectors, assure their carbon emissions, given the high environmental impact of their operations and external public pressure (Fan et al., 2021), although this is contestable, as earlier illustrated.

e) Corporate governance

Gender diverse boards, absence of Chief Executive Officer duality, and presence of corporate social responsibility committees, influence environmental initiatives decisions to mitigate carbon emissions of which carbon assurance is an example (Simic et al., 2023). This gives an understanding of some of the corporate governance drivers for the adoption of carbon assurance, as discussed in literature.

f) Carbon performance

The desire to improve carbon performance drives assurance of carbon disclosures. Literature discusses two levels of assurance (Vera-Muñoz et al., 2020). First, the limited assurance level is commonly purchased, however, it provides a modest verification of disclosed carbon emissions information, compared to reasonable assurance (Simnett et al., 2009; Vera-Muñoz et al., 2020). Second, the reasonable level, although less often purchased by New Zealand entities (Ryan & Tiller, 2022), provides a more comprehensive opinion about the state of disclosed carbon emissions, than the limited level of assurance. The question left to ask is, which level of assurance is most efficient in improving carbon performance? Evidence provided in literature shows that large US firms, that purchase reasonable assurance, improve their carbon performance

marginally in the years after assurance is sought. Nonetheless, carbon assurance as a strategy minimises legitimacy threats, and carbon performance (Rohani et al., 2023).

g) Firm size

Large firms purchase external assurance (Huggins et al., 2011), to minimise legitimacy threats from external stakeholders, given their high environmental impact (Moroney et al., 2012), visibility to public scrutiny, and media exposure (Chithambo & Taurigana, 2014; Datt et al., 2019; Dutta, P. & Dutta, A., 2021, Fan et al., 2021; Rohani et al., 2023). Literature, however, does not give insight into whether small firms like small and medium enterprises, subject to less public scrutiny and media exposure, would be incentivised to purchase carbon assurance given that, Busch et al. (2023) asserts that small and medium firms, are not mandated to disclose greenhouse gas emissions data.

h) Leverage

High leverage firms assure their carbon emissions disclosures, to minimise legitimacy and public scrutiny threats from debtholders (Datt et al., 2019), concerning the reliability of disclosed carbon emission information (Datt et al., 2018). Good quality information is crucial for any debt contract, and as such, firms seeking to acquire debt as a form of financing, will be expected to comprehensively disclose both financial and non- financial information, to enable appropriate firm valuation. Carbon assurance in this case, is seen as a tool of providing credible information, to debt holders (Datt et al., 2019).

To crown it all, several factors external and internal factors drive the adoption of carbon assurance. Climate change is one of the most influential external factors shifting firm operations from traditional to new corporate carbon accounting practices. This is partly driven by stakeholder pressures and carbon legislation only subdued by carbon assurance. Besides external factors, large firms exposed to high carbon risk, carbon information asymmetry, high leverage, and good carbon governance structures seek carbon assurance to minimise legitimacy threats.

3.4.2 Emerging themes on outcomes

a) Reporting integrity

Carbon assurance reduces management incentive to engage in earnings management, a factor of reporting integrity. Firm stakeholders have conflicting interests, and the board, should ensure that, company resources are maximumly utilised, while minimizing conflicts among such stakeholders. Earnings management, however, violates such compromises, and firms that

prioritize maximising shareholder returns, risk compromising stakeholders' interests, and will not be socially accepted (Bui et al., 2021). To alleviate this tendency, the carbon assurance literature notes that, disclosing, assuring carbon emissions, and having gender diverse boards, minimizes tendencies of engaging in earnings management, hence, improving reporting quality (Bui et al., 2021). In comparison, Luo et al. (2023), asserts carbon assurance enables firms to improve their reporting systems. In sum, carbon assurance minimises the pressure exerted on firms to only maximise earnings.

b) Carbon, climate change, and environmental disclosures

Literature notes that carbon assurance yields the same significant and positive impact for climate change (Dutta, P. & Dutta, A., 2021), and the quality of carbon (Luo et al., 2023), environmental (Moroney et al., 2012), lastly emissions (Mahmoudian et al., 2023) disclosures. In climate-change disclosures context, evidence provided in literature notes that large, listed Finish firms, that externally verify their climate-change information improve climate-change disclosures, because, external auditing monitors managers' incentive to hide and manipulate vital climate-change information (Dutta,P. & Dutta, A., 2021), Dutta,P. & Dutta, A., however, note that the types of assurance provider particularly, accounting assurors have no effect on climate-change disclosures.

Similarly, in the environmental disclosure, assurance improves the credibility and quality of environmental disclosure for Australian publicly listed firms (Moroney et al., 2012), however, just like Dutta, P. & Dutta, A., environmental disclosure quality is not influenced by the choice of assuror.

In agreement with the findings of climate-change disclosures and environmental disclosure, Luo et al. (2023) note that the complexity of collecting and analysing carbon emissions data, may give rise to errors and omissions thus, international firms are incentivised to assure to identify such omissions, and consequently guide management to modify reporting systems, and improve carbon disclosures.

In agreement with the findings of climate-change disclosures, environmental disclosure, and carbon disclosure quality, assurance improves the quality of disclosed greenhouse gas emissions, by improving the integrity of carbon management practices, particularly those focused on reducing greenhouse gas emissions, moreover assurance indirectly reduces cost of debt (Mahmoudian et

al., 2023). In sum, carbon assurance improves climate change disclosures, and the quality of carbon, environmental, and greenhouse gas emissions disclosures.

c) Credibility of carbon disclosures

Carbon assurance enhances credibility of greenhouse gas statements (Chatterjee, 2012; Tang & Demeritt, 2018), by increasing trust among stakeholders (Luo et al., 2023). In comparison, Green and Li (2012) agree that increasing reporting is one way of improving credibility of assured greenhouse gas emissions statement.

d) Firm value

Scholars (Astuti et al., 2023; Mahmoudian et al., 2023) consent that seeking independent carbon assurance increases firm value. Firms that assure their greenhouse gas emission disclosures, enjoy lower debt costs which encourages more investment in projects that reduce carbon emissions (Mahmoudian et al., 2023). In sum, assurance of carbon emissions improves the credibility and quality of reported carbon information, and other carbon, climate change and environmental disclosures. Additionally, carbon assurance enhances the value of a firm however, this depends on the degree of carbon information gap (Schiemann & Sakhel, 2019, as cited in Fan et al., 2021).

Overall, carbon assurance improves the quality of greenhouse gas statements, by recasting managers' focus away from solely maximising shareholders' returns, to fairly meeting all stakeholders' need. External assurance positively improves carbon, climate change and environmental disclosures as well as credibility of disclosures and firm value.

3.4.3 Emerging themes on challenges

a) Voluntary nature of carbon assurance

The practice of assuring greenhouse gas emission statements is still voluntary in some jurisdictions (Datt et al., 2018, 2019; Matsumura et al., 2014; Olson, 2010; Rohani et al., 2023; Zhou et al., 2016), and industries (Olson, 2010), hence, this brings other associated challenges. One of them is that different jurisdictions have different reporting and assurance standards (Tang, 2019). In Australia, for instance, the NGER Act of 2007, requires companies to accurately report emissions that rise above a given level under (Olson, 2010), similarly, Martinov-Bennie (2012) notes that Australia's Clean Energy Act of 2011, aims to have 20 percent emissions by the year 2050, while in America, California's Global Warming Solutions Act, also requires companies with high carbon emissions to report them. A lack of uniform assurance standard is challenging (Luo et al., 2023) because it compromises the credibility of reported information (Olson, 2010), worse

still, there is no room for comparability (Hay et al., 2023; Mia et al., 2019) and compatibility (Ratnatunga, 2007).

b) Governance challenges

a. Lack of appropriate governance structure

Reporting and assurance emissions is relatively new (Olson, 2010; Simic et al., 2023; Tang, 2019), compared to financial statement reporting and auditing (Martinov-Bennie, 2012). As such, there is less rigor applied to the disclosure and auditing of greenhouse gas emissions, compared to financial reporting and auditing (Martinov-Bennie, 2012; Olson, 2010). This is attributable to the stronger emphasis Australian reporting firms place on financial, rather than non-financial environmental information given its crucial role in assessing a company's sustainability (Martinov-Bennie, 2012). Consequently, management under look reporting and assurance of greenhouse gas statements, however, environmental information is currently considered equally important, given that a firm's impact on the environment also shapes its long-term sustainability. Evidence provided from Australia confirms this, where 51% of firms in high emitting sectors, consider carbon emissions information, as important as financial data (Kazemian et al., 2022).

b. Ineffective carbon emission measurement process

Additionally, there is consensus in literature that uncertainty and ineffective carbon emission measurement process and systems design affects the assurance of greenhouse gas emissions (Martinov-Bennie, 2012; Tang & Luo, 2014). This is the case because, capturing, recording, quantifying, compiling, and disclosing carbon emissions is a very complex and technical matter (Kazemian et al., 2022; Luo et al., 2023), and Australian firms wonder whether the existing carbon measurement systems are effective in recording carbon emissions (Martinov-Bennie, 2012). In agreement, Olson (2010), Martinov-Bennie and Hoffman (2012) note that unfortunately company data systems and controls for capturing, recording, and tracing carbon emissions are not well developed, which escalates chances of picking up the errors, when auditing greenhouse gas emission information. Interestingly, a recent study shows that Australian high emitting firms are knowledgeable about the measurement process. In sum, the absence of an accurate carbon measurement process and system, affects the accuracy and quality of audited carbon emissions statements.

c. Infrequent reporting of emissions

Infrequent reporting affects greenhouse gas emissions assurance, for instance, in Australia, companies were initially required to annually capture and disclose greenhouse gas emissions,

however, increased demand and significance of greenhouse gas emissions information, changed the reporting trend, now some companies, report their carbon footprint monthly. This infrequency in reporting challenges auditing greenhouse gas emissions disclosure (Martinov-Bennie, 2012).

d. Allocation of greenhouse gas emissions of assurance duties

Who should quantify, register, and report greenhouse gas emissions information, is another governance challenge cited in literature. Reporting and auditing of carbon emissions differs from the financial reporting and auditing, for instance, while disclosure and assurance of greenhouse gas emissions requires non-financial information, and is non- monetary, financial reporting and auditing on the other hand, is monetary and requires different expertise compared to non- financial auditing thus, duties related to the computation and reporting of financial information, are usually left to the finance team (Martinov-Bennie, 2012). Evidence from Australia shows that allocation of carbon emissions reporting and assurance duties is difficult given its distinctive nature (Martinov-Bennie, 2012). Recent attempts to categorise duties and responsibilities of assurors only resulted in conflicts (Xu & Andrew, 2021). Scholars thus, agree that assurance of greenhouse gas emission requires a multi-disciplinary integration of both technical and assurance skills for this new form of assurance (Kim et al., 2016; Olson, 2010). To further confirm this, Kim et al. observe that assurance teams over rely on a senior assuror with greenhouse gas emissions expertise in an experiment conducted in Australia, which created a biased greenhouse gas emissions statement, however the biased effects are lowered when senior assuror has financial expertise.

c) Associated challenges.

Voluntarily assuring carbon emissions, and the lack of assurance governance structures, have consequently given birth to other associated challenges. First, there are variations in the rationale of reporting and assuring greenhouse gas emissions, for instance, some firms report to show that they have a smaller carbon footprint compared to their peers in the industry, while others want to take advantage of the financial benefits of trading in the emissions market, and lastly, others, simply want to show that their carbon reduction programs are effective in lowering emissions. Second, greenwashing, a tendency of managers to report only good carbon performance without any visible appearance of areas of improvement (Fan et al., 2021; Olson, 2010) has been cited in literature as the most challenging consequence of voluntarily reporting and assuring greenhouse gas emissions. In sum, the voluntarily assuring carbon emissions, hinders the progress of the practice, because it gives no room for uniform assurance standards to benchmark performance, and above all, to minimise greenwashing tendencies among managers.

d) Measurement challenges

a. Carbon emission measurement costs

Changes from cost effective to costly greenhouse gas emissions measurement approaches, affect the cost of measuring, and assurance of carbon disclosures. Evidence provided in literature shows that when Australia firms change their measurement approaches from cost effective to more costly approaches, the cost of reporting and assurance of carbon emissions increases (Martinov-Bennie, 2012). Two approaches of measuring carbon emissions are given in literature, namely, the periodic, and continuous approaches (Martinov-Bennie, 2012). This aligns with recent findings that confirm that some Australian firms collect their carbon emission data monthly while others on a quarterly basis, moreover, firms from the transport industry collect carbon information only when required, while other industries are systematic in their collection of carbon information (Kazemian et al., 2022). According to Kazemian et al. this shows the minimum value that Australian firms attach to carbon management practices.

Nonetheless, literature observes differences between these measurement approaches. While the periodic measurement is cost saving, it is however, inaccurate, on the other hand, a continuous measurement approach, is accurate, but costly, Australian firms are hence restoring to the purchase of innovative technologies, to accurately capture their emissions, however this is affecting the cost of reporting and assurance of carbon emissions (Martinov-Bennie, 2012). Knechel (2021) agrees with Martinov-Bennie (2012) and notes that, firms must invest in new technology, given that this is a new market, which also involves new engagements. Simply put, carbon emission measurement approaches vary across industries, hence, compromises in measurement approaches, may affect the quality of reporting and subsequent assuring of disclosed carbon emission information. Mia et al. (2019) further notes a challenge of consistently measuring greenhouse gas emissions.

b. Accuracy in matching carbon emissions

Less knowledgeable about the sources of carbon emissions and how to measure and register the carbon emissions leads to less accurate matching of company emissions among Australian firms (Martinov-Bennie, 2012). This however contradicts with recent findings that indicate that Australian high emitting firms are knowledgeable about the measurement process (Kazemian et al., 2022). Nonetheless, both Martinov-Bennie (2012) and Kazemian et al. (2022) agree that measurement challenges lead to inaccurate and incomplete carbon emissions data, which affects the auditing process of carbon emissions.

c. Differing third-party assuror opinion

Differing third-party assuror opinion that arises from the use of different carbon emission measurement approach by specialist experts, affects the assurance of greenhouse gas emissions. This means that, each assuror arrives at a different conclusion regarding a firm's carbon performance. Perplexing is the matter that Martinov-Bennie (2012), asks "whose opinion should the company rely on?" In agreement with Martinov-Bennie (2012), Olson (2010) notes that converting operational carbon emissions data to greenhouse gas equivalent emissions is subjective, and hence varies depending on the assuror.

d. Data collection challenges

Challenges experienced in collecting carbon data hinder the assurance of greenhouse gas emissions. Recent evidence from Australia indicates that firms are concerned about the accuracy of collected carbon emissions data, the technical challenges, and environmental challenges faced when collecting the data moreover, data is collected by different teams (Kazemian et al., 2022), and yet there is no assurance provided for the accuracy of data for multinational corporations (Comyns, 2018).This coincides with the earlier findings that revealed that firms lacked appropriate systems to record data and hence, resorted to using excel spreadsheets (Martinov-Bennie, 2012). however, collection of climate data is carried out by different departments of the firm (Kazemian et al., 2022).

e) Environmental stewardship

The progress of greenhouse gas emissions assurance is currently hindered by a trend among reporting companies, to determine the level of environmental stewardship. Reporting companies, particularly those with a high market share in their respective industries, influence the whole supply chain, by taking on the role of an environmental steward for the rest of suppliers in the supply chain. This is challenging the independent auditing of the supply chain given that carbon emissions, as well as reduction initiatives vary across the suppliers (Olson, 2010).

f) Aggregation of global greenhouse gas emissions

Carbon assurance is still facing a challenge of accurately verifying reported carbon emissions, merged from global greenhouse gas emissions standard reporting. The practice, hence, still needs to meet the national inventory reporting requirements as provided in the Copenhagen Accord of 2009 (Olson, 2010).

g) Non-standard boundary conditions

There is a consensus in literature among scholars (Martinov-Bennie, 2012; Mia et al., 2019; Olson, 2010; Ryan & Tiller, 2022) that non-uniform boundary conditions, unclear standards, and information opaqueness across national, city, and industrial level hinder carbon assurance. This is attributed to the inconsistencies in implementing the evolving assurance standards to ensure transparency. This consequently increases the risk of counting carbon emissions (Olson, 2010) and greenhouse gas emissions (Ryan & Tiller, 2022) twice, thrice, or four times which affects greenhouse gas emissions assurance (Martinov-Bennie, 2012). In agreement with Olson (2010) and Martinov-Bennie (2012), Mia et al. (2019), Kazemeian et al. (2022), and Ryan and Tiller (2022) note that the overlapping measurements of scope 1, 2, and 3 among entities lead to double counting, and incorrect estimates of emissions. Absence of boundary conditions for reporting greenhouse gas emission affects the reporting of carbon and greenhouse gas emissions. Overall, substantial challenges facing the carbon assurance market originate mainly from voluntary nature of greenhouse gas emissions, the diversity in the assurance practice, and lack of regulation of the greenhouse gas assurance market. Evidence is clear that the market needs to be regulated (Green & Zhou, 2013).

h) Carbon assurance costs

Firms are reluctant to assure carbon emissions (Tauringana & Chithambo, 2015) partly attributed to the costs of assurance. Evidence provided in literature notes that cities shy away from the practice because of the presumed cost (Mia et al., 2019). In comparison, Matsumura et al. (2014) note that low carbon emissions firms withhold their carbon performance if the costs outweigh the benefits of disclosure, coinciding with Chatterjee (2012).

i) Alternatives to external assurance

The use of internal auditors affects the adoption of an external assuror. Much as internal auditor, are considered valuable and perfect alternatives to external assurances, and check whether data is accurate, just like an external auditor, they are, however, criticised for their limited expertise in greenhouse gas emissions assurance (Trotman & Trotman, 2015).

To crown it all, carbon assurance is challenged by governance, measurement, and other associated challenges. Addressing these solutions will contribute to the growth of the practice.

3.4.4 Growth opportunities of carbon assurance

Carbon assurance is a relatively new practice and is still evolving, the reviewer hence, assessed the potential drivers of carbon assurance growth and the following themes emerged.

a) Differentiation and competitive advantage

Publicly traded companies may be more competitive by differentiating themselves from their peers through greenhouse gas emissions assurance. This is so because assuring greenhouse gas emissions improves transparency, and reliability of carbon disclosures, which consequently, increases stakeholders' confidence (Vera-Muñoz et al., 2020). An increase in investor confidence, further gives rise to high demand for a company's publicly listed shares, which increases share price. Similarly, companies that prefer debt as an alternative source of finance besides equity, will enjoy lower cost of debt when high quality assured greenhouse gas emissions information is provided (Moroney et al., 2012; Olson, 2010). A credible assured greenhouse gas statement can further increase a company competitive advantage by demonstrating its effectiveness in reducing carbon emissions. Accurately disclosed carbon emissions and carbon reduction initiatives, provide evidence to stakeholders regarding the actions a company is undertaking to have environmentally friendly products, and processes. This, consequently, boosts the company' reputation, and yields greater returns from investors as well as, from the innovative technologies adopted to mitigate climate change (Olson, 2010).

b) Recognition and awards

Companies integrate sustainability initiatives into normal business operations, position themselves to be publicly recognised by society. Actions towards mitigating climate change are highly encouraged among firms, hence firms that go an extra mile to adopt carbon reduction projects and technologies, such as, clean energy, are often awarded by environmental orgnisations across the world. Recognitions such as these, not only acknowledge a firm's actions at reducing carbon emissions, but also boost the financial returns. In sum, provision of assured, disclosed carbon emissions poses immense recognition opportunities, for reporting firms, as well as other associated gains (Olson, 2010).

c) Reduced impact of global warming

Firms that assure their greenhouse gas emissions, join other nations, and firms adopting innovative strategies to reduce the impact of global warming. Disclosure of carbon emissions is thus, one-way firms signal their intention to mitigate climate change, because initiatives such as, low- carbon investments, consequently, reduce the impact of global warming, thus, verifying the credibility of such disclosed information, will in the long term, reduce the world's greatest threat (Olson, 2010). To crown it all, firms stand to distinctively outcompete their peers, gain stakeholders' trust and confidence if they assure their carbon disclosures. Firms that externally improve the quality of carbon disclosures, are often recognised by environmental organisations, which consequently, mitigates climate change as well as boost their financial returns.

3.5 Theoretical underpinnings of carbon assurance

Carbon assurance scholars use several theories to explain the phenomena. The following section discusses a few of the commonest and least applied theories as detailed in **Appendix 18**.

3.5.1 Stakeholders

The stakeholder's theory is the most applied theory in carbon assurance literature. The theory posits that there are many categories of stakeholders like environmental agencies, financial institutions, employees, managers, non-profit organisations, institutional investors, community, customers, suppliers, regulators (Luo et al., 2023). These stakeholders provide resources vital for the long-term sustainability of the firm. A firm is thus, accountable to all stakeholders and the environment (Luo et al., 2023). Carbon assurance as a climate change strategy act as a monitoring tool that ensures that managers meet all stakeholders' needs besides shareholders' (Bui et al., 2021; Luo et al., 2023)

3.5.2 Stakeholder- agency

This is the second most applied theory and is made up of both stakeholders and agency perspectives. The theory was first coined by Freeman (1984) and posits that a firm engages in several contracts with different stakeholders (Dutta. P. & Dutta A., 2021), thus, managers as firm agents engage in several binding relationships with stakeholders while striving to account, interact (Comyns & Figge, 2015) and meet the information needs (Comyns & Figge, 2015) of all stakeholders besides shareholders (Bui et al., 2021; Chatterjee, 2012; Datt et al., 2020; Datt et al., 2019; Dutta. P. & Dutta A., 2021; Mahmoudian et al., 2023; Zhou et al., 2016).

Scholars agree that stakeholders are different (Dutta. P. & Dutta A., 2021; Luo et al., 2023); in terms of; their climate change attitudes (Luo et al., 2023), the resources they invest into a firm (Dutta. P. & Dutta A., 2021), and hence they have different expectations (Dutta. P. & Dutta A., 2021); for instance, shareholders expect maximum return on their invested resources, while managers and employees too, want the best working conditions, given the time invested in progressing the companies' interests, and lastly, the communities that welcome firm investments and operations, also want to reap a good welfare, in exchange of the operation space and infrastructure they provide to the firms. The needs of stakeholders are thus diverse, and it is a firm's responsibility to maximise both financial and environmental performance to please all stakeholders (Datt et al., 2018). This means firms' long-term survival greatly depends on what stakeholders approve as right for the interests of the whole society, hence, firms that are sustainability-oriented, align organisational goals with stakeholders' interests (Bui et al., 2021;

Chithambo & Taurigana, 2014), and as such, have a role of disclosing good quality (Mahmoudian et al., 2023; Pitrakkos & Maroun, 2018) carbon emission information to positively influence stakeholders' decisions (Simic et al., 2023), or they risk affecting their legitimacy and survival if they operate outside the boundaries set by stakeholders (Chithambo & Taurigana, 2014).

Stakeholder-agency theory recognises that managers are links that bring together stakeholders' interests by optimally allocating resources to meet their needs (Dutta. P. & Dutta A., 2021). Carbon assurance, hence, monitors managers' incentive to withhold information from stakeholders by improving the processes of collecting data and discovering omissions, to improve climate-change disclosures (Dutta. P. & Dutta A., 2021). In sum, the stakeholder-agency theory advocates for fairness in terms of meeting all stakeholder's information needs and expectations, and best aligning a firm's reporting and assurance practices to stakeholders' expectations.

3.5.3 Legitimacy

The legitimacy theory follows closely with the notions set under stakeholders' theory and posits that firms with high legitimacy threats such as, high emitting firms will strive to legitmise their business operations to conform with society's expectations (Comyns & Figge, 2015; Datt et al., 2020), thus, such firm are drawn to adopt strategies, to counteract public scrutiny (Olson, 2010), arising from a firm's negative impacts on the environment (Datt et al., 2018; 2019), to improve credibility of carbon disclosures, improve public image (Busch et al., 2023), increase stakeholder confidence, and signal to external stakeholders, that their operations are in congruence with environmental and society interests (Datt et al., 2019). In sum, carbon assurance is used as a strategy to minimise legitimacy threats (Rohani et al., 2023).

3.5.4 Institutional

Institutional theory is also closely related to stakeholders' theory and posits that when increasing pressure from stakeholders like investors, governments, policy makers and non- government organizations is exerted through climate change policies, some firms adapt and make internal organisational changes in line with the stipulated legislation (Mateo-Márquez et al., 2020; Matsumura et al., 2014). The theory further posits that, institutional contexts shape organisational practices, by guiding firms to implement socially acceptable practices, and since contexts change, then organisational practices are also bound to change, as Comyns (2018) notes that multinational organisations subjected to different institutional climate-change pressures, consequently, adopt the same practices to minimise such pressures. This coincides with Mateo-Márquez et al. (2020) who note that firms in the same context, are often subjected to the same institutional pressures.

In the carbon assurance context, institutional theory helps to explain choices made by firms in response to institutional pressures, for instance, firms may react differently by adopting different carbon assurance approaches such as carbon management, compliance carbon audit, governmental climate audit, greenhouse gas emission statement assurance (Tang, 2019). Carbon assurance thus, minimises institutional pressures, by improving legitimacy and regulatory compliance, hence firms that belong to the same industry, adopt the same practices, when new social processes, like carbon assurance, are introduced (Comyns, 2018).

Scholars (Comyns, 2018; Luo et al., 2023) agree that there are three types of pressures that drive firms' adoption of new institutional practices. First, coercive pressures, through which firms formally or informally give in to government pressure to follow the set regulations. Second, mimetic pressures, through which firms copy other firms' practices, and lastly, normative pressures, where firms follow the norms of a professional field. The reviewed literature, however, considers mainly coercive pressures (Mateo-Márquez et al., 2020) that drive carbon assurance. Do mimetic and normative pressures influence the decision to assure carbon emissions? Moreover, since Mateo-Márquez et al. notes that these three types of pressures may be difficult to separate, then it would help to examine how these three types of pressures influence the assurance of carbon emissions.

3.5.5 Signaling

First coined by Jensen and Meckling (1976), this theory posits that managers who disclose high quality carbon emissions information, assure their carbon emission statements (Luo et al., 2023), and engage in carbon reduction initiatives, to send quality signals to the readers of such reports, about firm's transparency (Datt et al., 2018), and increased responsiveness towards environmental and social matters (Luo et al., 2023). The theory explains that stakeholders, particularly investors, may discredit voluntarily disclosed carbon emission statements, hence, carbon assurance acts as a signaling tool that enhances carbon disclosure quality (Luo et al., 2023). In sum, high quality disclosures, lead to assurance of carbon emissions, as a mechanism to signal to external stakeholders, their commitment to social, and environmental initiatives.

3.5.6 Credibility enhancement

Under this theory carbon assurance improves the credibility of disclosed carbon emissions by increasing communication and trust between a firm and its stakeholders. The verification of misstatements or errors in the carbon emissions statement improves carbon emission reporting and credibility of carbon emissions performance, which consequently satisfies and meets the

needs of diverse stakeholders. Firms driven to enhance the credibility of carbon emissions usually operate in sectors with less carbon intensity and in countries with stakeholder orientation. Such firms are usually motivated to improve the systems of reporting emission information to fulfill their responsibility to all stakeholders (Luo et al., 2023).

3.5.7 Outside-in-management view

The outside-in-management perspective posits that firm processes and performance can be improved by implementing external stakeholder views (Rohani et al., 2023). Carbon assurance, hence, acts as an outside-in chance to enhance performance, thus, purchasing a higher level of assurance can provide a firm with more explanation regarding stakeholder expectations, which when implemented, can improve performance (Rohani et al., 2023). This theory is well aligned with stakeholders' theory in a way that, when a firm is made aware of stakeholders' expectations, they can match their reporting and assurance frameworks to stakeholder needs (Luo et al., 2023).

3.5.8 Carbon information asymmetry

This theory originated from information asymmetry theory which posits that internal managers hold more information than the owners the firm (Myers,1984). Firms which withhold carbon information are charged with high finance costs as investors price protect their investment due to an inability to accuracy calculate firm value (Fan et al., 2021). Information asymmetry is often used in financial audit, however, Fan et al. extends the theory to the carbon context, to highlight that high information asymmetry influences carbon assurance adoption through a need to enhance carbon disclosure credibility.

3.5.9 Transition management

This theory posits that, actors affected by transition, can either enable the change or deter the transition, hence, actors are instrumental in the transition. In carbon auditing context, firms are acts and carbon assurance is a signaling and transition management tool that communicates to regulators, firms' effectiveness in utilising green funding resources, as well as the key areas of implementation of green projects to aid low- carbon transitional change (Tang, 2019). In sum, external and internal factors drive the adoption of carbon assurance. Firms may enhance report quality or lower their cost of debt when they assure their carbon emissions. However, the formative practice brings associated challenges, whose resolution will advance scholarship and practice, given the tremendous impact of reducing global warming. The desire to minimise stakeholder pressures, abide with carbon legislation drives carbon assurance adoption.

Chapter 4: Discussion of Literature Review

4.1 Introduction

Carbon assurance scholarship is steadily gaining attention. The formative state of literature provides a few and less integrated definitions of carbon assurance. Of the four existing approaches of carbon assurance, the greenhouse gas statement assurance, is greatly studied than the remaining three, although the process of implementing all three approaches has commonly received the least attention. Scholarship is mainly drawn to examine more firm level incentives than country level antecedents of carbon assurance, although minimal focus is placed on individual managers' incentives and other corporate governance antecedents. Moreover, besides enhancing firm value, carbon assurance may improve the credibility, and quality of carbon reporting, although more outcomes are still unexplored in literature. Lastly, the theorisation of carbon assurance, takes on a wide range of presumptions, with notable similarities and differences, however, rather than apply the theories in isolation, there's a need to integrate the theories, to increase our understanding of the carbon assurance phenomena.

4.2 Redefining carbon assurance.

Regardless of the few, and diverse definitions shown in **Table 8**, it is consented in literature that, first, carbon assurance is an element of sustainability assurance (Datt et al., 2018, 2019). Second, the practice is driven by legitimacy concerns, carbon legislation, and public awareness about climate change (Datt et al., 2019). Third, carbon assurance is conducted by an external third-party auditor (Tang, 2019). Fourth, greenhouse gas emissions are the subject matter of this form of assurance (Green & Zhou, 2013; Ryan & Tiller, 2022; Tang, 2019), and lastly, carbon assurance enhances confidence of greenhouse gas statement users (Tang, 2019). Mindful of the diverse understanding of carbon assurance, there is hence, a need to integrate the definitions to aid scholars in study of carbon assurance. Scholars may thus define carbon assurance as, an examination of greenhouse gas emissions statements conducted by a third-party auditor, for an organisation responding to legitimacy, carbon legislation, and public climate change concerns, that enhances the confidence of greenhouse gas emissions statement users.

The review also notes that carbon assurance is used interchangeably with other names such as assurance of greenhouse gas emissions, external assurance, assurance of carbon disclosures, carbon auditing, climate change auditing (Tang, 2019). This diversity echoes the need to have one name, to reduce ambiguities in the search for literature, hence adopting carbon assurance as a common name will resolve this.

4.3 Review of carbon assurance approaches

Four carbon assurance approaches namely, assurance of greenhouse gas statement, compliance carbon, carbon management, and governmental climate change audit are acknowledged in only one study (Tang, 2019). A few scholars discuss carbon audit compliance (Green & Zhou, 2013) and carbon management audit (Kazemian et al., 2022; Tang & Luo, 2014) minimally, while majority (Busch et al., 2023; Comyns & Figge, 2015; Ekasingh et al., 2019; Green & Li, 2012; Hay et al., 2023; Lodhia & Martin, 2012; Martinov-Bennie & Hoffman, 2012; Mateo-Márquez et al., 2020; Mia et al., 2019; Zhou et al., 2016) put more emphasis on assurance of greenhouse gas statement, thus, the commonest carbon assurance approach compared to the three approaches which have a limited presence in literature. The findings from the review have revealed that the carbon assurance approaches are under researched, this gives enough justification for conducting the review, one of which was to highlight the least researched areas.

The review further notes that the four approaches are present in China, while greenhouse gas statement assurance is common in Australia, UK, USA, and other countries (Green & Zhou, 2013; Kazemian et al., 2022; Tang, 2019) with a small presence in emerging countries like South Africa (Datt et al., 2018). Moreover, the approaches are common in countries with emission reporting schemes (Green & Zhou, 2013; Zhou et al., 2016) and other carbon institutions (Tang, 2019).

The approaches are unique in terms of purpose hence, one approach cannot be substituted for another, greenhouse gas statement assurance for instance, assesses whether greenhouse gas statements are a true presentation of a firm's carbon footprint, while compliance carbon audit determines a project's compliance with regulation. Additionally, differences in scope exist, for instance, greenhouse gas statement assurance focusses on firm greenhouse gas emissions, and lastly, governmental climate change audit focusses on either national or international greenhouse gas emissions. Furthermore, the nature of assurance distinguishes the four carbon assurance approaches, for instance, while greenhouse gas statement assurance focusses on verification, compliance carbon audit on the other hand, is investigative. Lastly, while external users use greenhouse gas statement assurance, on the other hand, both external and internal managers use compliance carbon audit reports (Tang, 2019).

In sum, literature gives insight into the variations in carbon assurance approaches, however, our understanding of user expectations and perceptions in terms of report quality, uses of the reports, and user preferences for assurance provider is unknown. Chatterjee (2012) confirms that the nature of information, length, preparation of the report is unclear. Further engagement shows that,

although distinguishing features are identified, little emphasis is placed on the definition, antecedents, process, outcomes, and challenges of implementing all approaches.

Reviewing the drivers of the carbon assurance approaches, reveals an overwhelming focus given to greenhouse gas statement assurance, compared to the three other approaches. Greenhouse gas assurance is relatively older than the rest of the approaches, hence this could explain the limited literature on the three approaches. Country-level factors like, carbon institutions and government green funding drives the adoption of all four approaches in China (Tang, 2019), on the other hand, adoption greenhouse gas statement assurance, in Australia, United Kingdom, and other countries, is driven by both country-level and firm-level factors such as; carbon risk exposure, carbon emissions disclosure, carbon governance mechanisms (Comyns, 2018; Datt et al., 2018, 2019; Dutta,P. & Dutta, A., 2021; Fan et al., 2021; Kazemian et al., 2022; Luo et al., 2023; Olson, 2010; Rohani et al., 2023; Simic et al., 2023; Zhou et al., 2016). Other individual level factors, and size of the board, board tenure are under looked in literature despite their probable influence on carbon assurance.

The review highlighted consequences of assuring carbon emissions, which include improving reporting quality, carbon, climate change, environmental, and greenhouse gas disclosures. The few mentioned outcomes, confirm the formative state of literature, and scholars' limited focus on investigating this research area (Luo et al., 2023) despite calls to understand the effects of carbon assurance (Bui et al., 2021). On this basis, carbon assurance effect on; carbon reduction investments, investors' investment judgements, operating performance, carbon management, carbon performance should be investigated.

The process of assuring all four approaches is under studied. Scholars have repeatedly reechoed the need to use case studies, to investigate how carbon assurance is practically carried out (Datt et al., 2018). Additionally, literature highlights only the challenges facing greenhouse gas assurance, while under looking challenges facing other carbon assurance approaches, and yet it is possible that there may be unique challenges affecting them. Lastly, it is possible for a firm to verify the greenhouse gas emissions statement and check for compliance, hence, it would be interesting to examine what factors may drive the adoption of two, three or all approaches to carbon assurance.

4.4 Reviewing emerging themes in carbon assurance.

4.4.1 Reviewing antecedents of carbon assurance.

Several scholars focus entirely on assurance of carbon emission drivers (Datt et al., 2018, 2019; Tang, 2019; Zhou, 2016). Literature organises the drivers into two categories (Zhou et al., 2016). First, firm level factors are subdivided into three; first, the corporate governance factors such as, gender diversity, corporate social responsibility committees; second, the carbon governance factors such as, environment committees, proactivity, and carbon reduction; and lastly, other factors such as, carbon risk exposure, carbon disclosures. Second, country level factors which include, climate change, carbon regulation, and industry pressures, among others (Comyns, 2018; Datt et al., 2018, 2019; Dutta, P. & Dutta, A., 2021; Fan et al., 2021; Kazemian et al., 2022; Luo et al., 2023; Olson, 2010; Rohani et al., 2023; Simic et al., 2023; Tang, 2019; Zhou et al., 2016).

Externally, climate change greatly influences carbon assurance. This is right because, without this catastrophe, carbon assurance as a strategy to mitigate its effects, would be unnecessary. Additionally, firms are considered triggers of greenhouse gas emissions, that cause climate change (Luo et al., 2023) hence, they adopt mitigation strategies (He et al., 2022). Awareness of climate change has thus, increased institutional pressures among governments, firms, and cities (Comyns, 2018; Mia et al., 2019; Tang, 2019) to mitigate climate change.

Interestingly, emergence of climate change phenomena, consequently, yields other drivers of carbon assurance, for instance, because of global warming, countries enforce regulations that control emissions thus, countries with ecological protection systems and emissions trading schemes (Fan et al., 2021; Tang, 2019), encourage verification of carbon disclosures to reduce stakeholders' pressures (Fan et al., 2021; Tang, 2019). Furtherstill, climate change has driven carbon disclosures, inputs for other carbon initiatives (Green & Zhou, 2013) of which assuring carbon emissions, is an output (Fan et al., 2021).

Thirdly, a country's business culture drives the adoption of carbon assurance. Literature mentions two forms of business culture, namely, stakeholder, and shareholder-orientation, firms operating in a civil law system of governance purchase assurance, and the reverse holds for those in shareholder- orientation (Luo et al., 2023; Zhou et al., 2016).

Industrial factors as antecedents of carbon assurance yield mixed results. While Green and Zhou (2013) assert that carbon intensive firms assure carbon disclosures, more recent studies (Luo et

al., 2023; Simic et al., 2023), however, note that high emitting firms, assure their carbon emission statements.

Fifthly, Chinese firms benefiting from government investment in low carbon projects are driven to verify their greenhouse gas statements and minimise the incentive to divert carbon reduction resources into other projects. Carbon audit thus, monitors such tendencies by investigating how well firms utilise government resources (Tang, 2019). However, are firms from developing countries, that benefit or do not benefit from government low carbon projects, driven to adopt carbon audit? Second, do mimetic, and normative pressures among other factors drive the adoption of carbon assurance?

Switching to internal antecedents, firms with high carbon risk, operating in high emitting industries, assure their carbon disclosures (Datt et al., 2018, 2019), to reduce high public scrutiny (Datt et al., 2018, 2019; Olson, 2010), and legitimacy threats (Datt et al., 2018, 2019; Rohani et al., 2023). Do low public scrutiny, carbon risk, small sized firms, that disclose outside the carbon disclosure project assure carbon emissions?

Good carbon governance structures, as carbon governance mechanisms, drive the need for carbon assurance. Managers as agents of firm owners, are tasked with meeting stakeholder needs, while transparently disclosing actions undertaken. Transparency may be achieved through carbon assurance, which also improves quality and credibility of disclosed information, to guarantee long-term collaboration with stakeholders (Datt et al., 2018).

Environmental committee as a second carbon governance mechanism, influences greenhouse gas emissions assurance, and signals firm's actions to heed to sustainability calls. Boards are responsible for allocating firm resources, towards both financial and climate change mitigating projects, to meet stakeholders needs. Disclosure and assurance of carbon emissions, hence, becomes inevitable, since stakeholders need evidence of resource allocation in carbon reduction projects (Datt et al., 2018).

Favorable compensation (Simic et al., 2023), and incentives (Datt et al., 2018) packages, encourage management, and employees to reduce carbon (Datt et al., 2018). Firms that align sustainability incentives to executive compensation packages, thus, purchase carbon assurance, to enhance credibility, given executives' incentive to disclose incorrect or good carbon performance, to get higher remuneration and incentives, which weakens the very ease of carbon disclosure (Simic et al., 2023), however, how can executives' compensation and incentive

packages be aligned with carbon reductions targets, without compromising stakeholders' interests?

The need to achieve carbon transparency, drives firms to assure their carbon emission statements. Stakeholders' confidence in the quality of disclosed information, is crucial in business engagements, thus, firms who prioritise improving stakeholders' trust, assure greenhouse gas emissions, carbon management mechanisms, and carbon reduction initiatives, to communicate their responsiveness in mitigating climate change (Datt et al., 2018).

Proactivity distinguishes firms. More proactive firms quickly innovate projects to reduce carbon, and assure carbon disclosures, to improve processes and systems, but most importantly, to mitigate climate change (Datt et al., 2018). Luo et al. (2023) agree that actions such as these, signal to external stakeholders, firms' responsiveness to social and environmental concerns.

There is, however, a lack of consensus in literature regarding carbon information asymmetry, a driver of carbon assurance. Fan et al. (2021) assert that, carbon assurance reduces carbon information asymmetry by monitoring managers' greenwashing tendencies. Datt et al. 2018, however, assert that information gaps may not be reduced when poor performers assure to cover up the understated carbon emissions. Although both Fan et al. and Datt et al. agree that high emitters, purchase carbon assurance. Literature under this theme, hence, does not confirm whether carbon assurance removes greenwashing tendencies among managers. Still under this theme, literature asserts that complex energy structures and industry, drives the need for assurance, however, what an incentivises small, low carbon, unlisted firms, and with less complex energy structures, to assure their carbon disclosures remains unanswered in literature.

Further still, diversity of boards in the form of gender, CEO duality, and presence of corporate social responsibility committees, influences assurance of carbon disclosures (Simic et al., 2023). Literature is, however, silent about, other corporate governance factors such as board tenure, expertise, and independence of audit committee, among others, which may influence the assurance of carbon disclosures.

Literature asserts that firms adopt carbon assurance to improve their carbon performance. Scholars under this theme debate about, which level of assurance, can possibly improve a firm's carbon performance. Evidence shows marginal improvements in carbon performance in the years after purchase of higher-level carbon assurance, for large US firms (Rohani et al., 2023). Does the purchase limited level of assurance improve carbon performance? Second if higher levels of

assurance do not improve carbon performance significantly, then what can motivate firms to purchase more expensive, higher level of assurance? These two questions remain unanswered.

The size of the firm drives assurance of greenhouse gas emissions. Evidence notes that large firms subjected to public scrutiny and constant media exposure for their high environmental impact, drive adoption of carbon assurance to minimise legitimacy threats (Datt et al., 2019). Literature, however, does not give insight whether firms subjected to less public scrutiny and invisible to the media, assure carbon disclosures.

Lastly, high leverage drives firms to purchase carbon assurance, to mimimise legitimacy threats from debtholders, improve firm image, credibility, and quality of disclosed carbon emissions, which greatly influences firm value, in the debt contractual agreement (Datt et al., 2019). However, are low leverage firms incentivised to assure carbon disclosures? All in all, the antecedents of carbon assurance are sufficiently researched, although knowledge gaps remain. Datt et al. (2018) agrees that the decision to assure carbon emission disclosure is complex, and hence requires a thorough analysis of more driving factors.

4.4.2 Reviewing outcomes of carbon assurance.

This theme is under researched (Luo et al., 2023). This is attributed to the narrow focus on carbon emissions, whose assurance is carried out under sustainability (Zhou, 2022). Nonetheless, carbon assurance impacts firm value (Astuti et al., 2023; Mahmoudian et al., 2023), integrity of reports (Bui et al., 2021), and significantly improves climate change (Dutta, P. & Dutta, A., 2021), and the quality of carbon (Luo et al., 2023), environmental (Moroney et al., 2012), and greenhouse gas emissions (Mahmoudian et al., 2023) disclosures. How does carbon assurance moderate carbon information asymmetry and value of a firm relationship, given its dependability on the degree of carbon information asymmtery (Schiemann & Sakhel, 2019, as cited in Fan et al., 2021). Second, what is the influence of carbon reduction investments, investors' investment judgements, operating performance, carbon management, carbon performance on carbon assurance adoption? Luo et al. asserts that carbon assurance may affect carbon management.

4.4.3 Reviewing challenges of carbon assurance.

The carbon assurance market is unregulated (Fan et al., 2021), thus, characterised by multiple non-uniform national and international emissions standards (Datt et al., 2019). The understanding of how the market should be regulated and harmonised amidst the diversity in assurors, and assurance standards is limited. Studies that focus on the dichotomous groups of assurors, note an observed pattern for specialist firms to use both accounting and specialist standards, with a

further expectation to use the greenhouse gas standard ISAE 3410 than ISAE 3000 or AA1000, however, what implication does adopting a single assurance standard have over a combination of standards? Second, what implication does ISAE3410, have on the assurance practice over the preexisting standards? Third, what drives assurance standards choice, and how does it affect quality of engagement?

Carbon assurance is still voluntary in some jurisdictions and industries (Datt et al., 2018; Olson, 2010; Rohani et al., 2023). This has given rise to other associated challenges. Besides the variations in assurance rationale, voluntary carbon disclosure, encourages greenwashing (Fan et al., 2021; Olson, 2010). Moreover, there are further concerns that, carbon assurance, may not always reduce greenwashing tendencies and information gaps (Datt et al., 2018). How can greenwashing be minimised? Second, do firms mandated to disclose carbon emissions, have fewer greenwashing tendencies, compared to those who voluntarily disclose? These are still unexplored.

Besides the voluntary assurance, the lack of appropriate governance structure affects the rigor of auditing greenhouse gas emissions (Martinov-Bennie, 2012; Olson, 2010). This is attributable to the stronger emphasis placed on financial rather than non-financial information (Martinov-Bennie, 2012). Recent literature, however, shows a disagreement with earlier findings surrounding which type of information is more relevant for the firm, for instance, evidence provided from Australia shows that 51% of firms in high emitting sectors, consider carbon emissions, as important as, financial data (Kazemian et al., 2022). This in its totality, highlights the need to improve the governance of carbon assurance, to consequently increase the practice's rigor.

Scholars (Martinov-Bennie & Hoffman, 2012; Olson, 2010), agree that ineffective measurement processes affect the capturing, recording, and tracing of carbon data which cause errors in auditing greenhouse gas emissions. Literature however, highlights that Australian high emitting firms are knowledgeable about the measurement process (Kazemian et al., 2022), however, if the process is well understood, have measurement errors, previously recorded, reduced? If not, then what is still causing the prevailing errors in measurement, and what improvements should be made in measuring and reporting carbon data? This is crucial because, the absence of an accurate carbon measurement process and system, affects the accuracy of reported information, and quality of audited carbon emissions statements (Ioannou et al., 2016).

Infrequent nature of greenhouse gas emissions reporting is cited in literature as another governance challenge affecting the assurance of greenhouse gas emissions. Australian,

companies that previously reported greenhouse gas emissions information annually, however, report monthly (Martinov-Bennie, 2012). However, can't monthly reports be aggregated into annual reports? How does infrequency in reporting affect carbon auditing? This is unexplored.

Allocation of assurance duties is another governance challenge. Reporting and auditing of emissions is a new and unique market, that requires different expertise, and an integration of both technical and assurance skills compared to financial auditing (Ekasingh et al., 2019; Green et al., 2009; Huggins et al., 2011; Kim et al., 2016; Martinov-Bennie, 2012; Simic et al., 2023; Tang, 2019). Having a multidisciplinary team is, however, not the main challenge, but rather, the tendency for the assurance teams to overly rely on the specialist expertise, while second guessing collected evidence (Kim et al., 2016). This affects carbon assurance because it creates biased, misstated carbon emission statements. This theme has interesting knowledge gaps, for instance, does the multidisciplinary team fully integrate or do two separate expertise teams exist (Kim et al., 2016). Second, previous studies focus on team effectiveness and team performance (Kim et al., 2016; Ekasingh et al., 2019) respectively, however, no study to the best of my reading, has focused on multidisciplinary teams' effect on greenhouse gas emissions assurance quality. This is important because if multidisciplinary teams are formed to fill knowledge gaps, in quantifying and assuring greenhouse gas emissions, then it should be the case that the quality of greenhouse gas statement is improved, moreover, a comparison of quality of greenhouse gas statement, assured by a multidisciplinary team versus a financial or specialist assurance team, would yield even more interesting findings.

In terms of measurement challenges, changes from cost effective to costly measurement approaches, consequently, increase reporting and assurance costs (Martinov-Bennie, 2012), but does the choice of measurement approach, affect the quality of greenhouse gas emission statement? This remains unanswered.

Accuracy in matching company emissions, caused by limited knowledge about emission sources, affects carbon assurance. Martinov-Bennie (2012) notes that this is challenging because, it leads to incomplete carbon emissions data, which affects carbon auditing. How can the measurement process can be improved? Differences in third-party assuror opinions affect greenhouse gas emissions assurance. Literature shows that differences in carbon measurement approaches, lead to differences in expert opinion (Olson, 2010).

Other challenges include a company trend of reporting carbon emissions for the whole supply chain. This is an interesting area to explore in terms of finding avenues of accounting for carbon

emissions for all suppliers in the supply chain. This may reduce double counting risks, but also, may ensure an account of all carbon emissions and their sources, instead of focusing on one reporting company. This would solve the challenge of aggregating global greenhouse gas emissions as mentioned by (Olson, 2010).

Lastly, non-standard boundary conditions and inaccuracies in greenhouse gas emissions reporting consequently affect carbon emissions assurance. A lack of uniform boundary conditions increases risks of counting carbon emissions (Olson, 2010), and greenhouse gas emissions (Ryan & Tiller, 2022) twice, thrice, or four times. This challenge further points to the need to have uniform standards, to reduce information opacity across national and industrial levels (Olson, 2010).

4.5 Theoretical underpinnings

The review sought to understand the theoretical underpinnings used in carbon assurance research. Out of the 52 articles reviewed, 25 applied a theoretical underpinning or a combination of theories, followed by 10 studies, which although empirical, did not apply a theoretical underpinning, and lastly, 17 studies applied no theoretical underpinning. All in all, majority of the review studies used a theoretical underpinning or a combination of theories to guide their studies as shown in **appendix 18 and appendix 19**. In the early years between 2007 and 2011, 7 studies used no theoretical underpinning while 1 was empirical but used no theoretical underpinning. Stakeholder agency theory was the first underpinning used in 2011. From 2012 to 2023, a wider range of theories including stakeholder, stakeholder-agency, legitimacy, institutional, signaling, resource dependance, credibility enhancement were used to guide the studies.

Literature asserts that, the theories are categorised into three groups; first, social political theories that include, legitimacy, and stakeholder (Chithambo & Taurigana, 2014; Mateo-Márquez et al., 2020; Tang, 2019). Second, economic theories of disclosure, which include, signaling, carbon-information asymmetry, agency (Chithambo & Taurigana, 2014; Mateo-Márquez et al., 2020). Third, corporate governance theories that include institutional (Mateo-Márquez et al., 2020; Trotman & Trotman, 2015).

Literature acknowledges that the stakeholder- agency concept, is built on the presumption that an organisation has other stakeholders besides shareholders, who are different in terms of their climate change attitudes (Luo et al., 2023), expectations, and resources they provide (Dutta. P. & Dutta A., 2021). Managers as agents, are accountable to, and should treat all stakeholders fairly (Bui et al., 2021). Fairness may arise from taking responsibility for all invested resources, by

optimally allocating them, to meet all stakeholders' needs (Dutta. P. & Dutta A., 2021; Moroney et al., 2012) as well as, disclosing, good quality, credible carbon emission information (Mahmoudian et al., 2023; Pitrakkos & Maroun, 2018; Simic et al., 2023), mainly accomplished through assuring carbon disclosures. A firm's long-term survival greatly depends on meeting stakeholders' needs and receiving their approval for all actions undertaken in the business.

There appears to be more similarities than differences between the theories, for instance, legitimacy theory seems to closely follow with the notions set under stakeholders-agency, signaling, and credibility enhancement concepts, in terms of what firms hope to gain from assuring carbon emissions. To illustrate this, legitimacy theory posits that firms with high legitimacy threats such as, high emitting firms, are drawn to adopt strategies, to counteract public scrutiny (Olson, 2010), to minimise legitimacy threats, improve the credibility of disclosed carbon emission information (Luo et al., 2023), increase stakeholders' confidence, and signal to external stakeholders, that their operations are in congruence with environmental, and society interests (Datt et al., 2019).

In the same manner, stakeholder-agency and legitimacy theory seems to follow closely with the notions set under institutional theory, for instance, the institutional concept assumes that firms that belong to the same institutional context such as, an industry, are governed by a set of institutional rules, and structures, hence, are driven to adopt the same practices when new social processes are introduced, to improve their legitimacy before regulators as the stakeholders. This coincides with the stakeholders- agency theory that posits that firms operating in highly industrialised sectors are subjected to stakeholders' pressure which motivates carbon disclosure and audit (Bui et al., 2021). Additionally, stakeholders' theory posits that firms that operate outside the boundaries set by stakeholders, risk losing their legitimacy (Chithambo & Taurigana, 2014).

The transition management theory equally seems to follow closely with signaling, where carbon auditing is a signaling tool, to regulators, about firm's effectiveness in utilising green funding resources, given that the opinions provided by assurors signal to regulators, the improvement areas in the implementation of green projects (Tang, 2019). Further still, the outside-in-management view is well aligned with stakeholders' theory in a way that when a firm is made aware of stakeholders' expectations, they can match their reporting and assurance frameworks to stakeholder needs (Luo et al., 2023). In sum, although legitimacy and stakeholder theories are currently dominating the research field, it is however, imperative for scholars to theorise carbon assurance better by considering a unified theory to explain the phenomena.

Chapter 5: Formulated research questions, and conclusion

The structured carbon assurance review conducted between the years of 2007 to 2023 has revealed that the practice is relatively new, novel, unique, and diverse compared to financial audit moreover, it transcends many continents, although solely least practiced in Asia and Africa. The recent emergence of the construct may perhaps speak to the few attempts made to define it in literature.

Although carbon assurance has varying terms, the construct has four clearly identified approaches, that differ in terms of, the definition, purpose, scope, nature, users of assured statements, antecedents, process, outcomes, and limitations, although under researched. This diversity emphasises the richness of carbon assurance, as well as, the great opportunities that lie ahead for both scholarship and practice, as we transition to a zero- carbon future.

The formative nature of the construct speaks to scholars' strong emphasis on the antecedents of carbon assurance, though the complexity of assuring a technical subject matter like greenhouse emissions, requires a more thorough investigation of other drivers. Nevertheless, assurance of carbon emissions, is driven by the need to minimise institutional and legitimacy threats, meet all stakeholder needs, enhance credibility of carbon disclosures, signal firms' responsiveness to social and environmental concerns, minimise carbon information asymmetry to achieve a low-carbon economy.

An examination of the carbon assurance process is a gem yet to be explored, thus, for scholarship and practice to grow, scholars should investigate how assurance of carbon emissions is practically conducted. Although the outcomes give an attestation to carbon assurance effects on report integrity, environmental, and climate-change disclosures, scholarship should investigate more consequences of assuring carbon emissions.

Being relatively new, the practice is still voluntary, has differing assurance standards, which hinder its growth. Furtherstill, the evolving nature of carbon emissions measurements and reporting increases greenwashing tendencies among managers when disclosing carbon emissions, though the introduction of ISAE 3410, gives reassurance for improvement. In sum, the review has defined carbon assurance, identified the approaches, emerging themes, and the theoretical underpinnings in literature. As earlier emphasised, carbon assurance is relatively new, and hence, several themes remain unexplored. The following is an outline of the unexplored areas of research under carbon assurance.

5.1 Future research

5.1.1 Defining carbon assurance.

The review findings provide substantial evidence of the limited scholarly effort that has been put into defining carbon assurance moreover, the few definitions available lack an integrated approach to defining the construct, thus future research should address this gap in literature by answering,

a. What is carbon assurance?

5.1.2 Carbon assurance approaches

The structured literature review sought to examine the approaches used in carbon assurance. Evidence, however, reveals that the approaches are under looked in literature with an overwhelming focus on one carbon assurance approach, greenhouse gas emissions assurance, despite the existence of three more approaches. The explicit definitions, antecedents, process, outcomes, and challenges of the carbon assurance approaches are not well known. Scholars should thus examine the following questions for each of the four carbon assurance approaches.

b. What are the definitions, antecedents, process, outcomes, and challenges of each of the four-carbon assurance approaches?
    i. How are the carbon assurance approaches defined?
    ii. What drives the adoption of the carbon assurance approaches?
    iii. How are carbon emissions assured?
    iv. What are the outcomes of the carbon assurance approaches?
    v. What are the challenges faced in implementing the carbon assurance approaches?

Additionally, there was an absence of interactions among carbon assurance approaches, and yet it is possible that a firm may seek both to verify the greenhouse gas emissions statement, as well as check for compliance with regulatory requirements, hence, there is need to investigate the following,

c. What factors drive the adoption of a combined carbon assurance approach?
    i. What factors drive the adoption of compliance carbon audit and greenhouse gas emissions assurance?
    ii. What factors drive the adoption of carbon management audit and greenhouse gas emissions assurance?
    iii. What factors drive the adoption of greenhouse gas emissions assurance, compliance carbon audit, and carbon management audit?

5.1.3 Antecedents of carbon assurance

The factors driving carbon assurance adoption as earlier reviewed, are sufficiently researched, however, there are still some under looked corporate governance drivers that are worth investigating, thus, the following should be examined.

d. How does size and tenure of the board, female executive directors, CEO global working experience, board independence, board meetings, board financial expertise, expertise and independence of the audit committee, non- executive directors, social performance disclosure, effectiveness of the corporate social responsibility committee influence carbon assurance adoption?

5.1.4 Outcomes of carbon assurance

Literature provides little evidence about the consequences of assuring carbon emissions; thus, the theme is under researched (Luo et al., 2023). Evidence from the literature shows that carbon assurance effects on firm value, depends on carbon information asymmetry, however our understanding of carbon assurance moderating effect on carbon information asymmetry and value of a firm, particularly cost of debt relationship is unknown. Future studies should thus investigate,

e. What is carbon assurance moderating effect on carbon information asymmetry and cost of debt relationship?
    a. What is the effect of carbon information asymmetry on the cost of debt?
    b. What is carbon assurance moderating effect on carbon information asymmetry and cost of debt relationship?

Furtherstill, since carbon assurance if one of the four themes of carbon accounting, it is hence, likely that assuring carbon emissions may influence carbon management as well as carbon reduction investments, investors' investment judgements, operating performance. To grow scholarship, it is worth investigating.

f. What is carbon assurance effect on carbon management, carbon reduction investments, investors' investment judgements, operating performance?

5.1.5 Carbon assurance challenges

Assurance of carbon emissions is still emerging with unregulated market, lacks uniform assurance standards, carbon emissions measurement approaches still need improvements and greenwashing tendencies persist. Future research should thus examine ways of solving the following challenges to improve practice.

g. How should carbon assurance standards be integrated will considering the diversity among assurors?
h. How can greenwashing be minimised?
i. How can measuring, reporting, and assurance of carbon emissions be improved?

5.1.6 Theoretical underpinnings of carbon assurance

Carbon assurance studies use several existing theories like; stakeholders, legitimacy, and institutional theories to explain the carbon assurance phenomena. Although these theories are similar and diverse as highlighted in the findings, there is need for a new unified theory to help scholarship better understand carbon assurance.

The institutional theory posits that firms subjected to coercive regulatory pressures are driven to assure their carbon emissions to minimise such pressures, however, besides coercive pressures, firms may imitate other firms' practices or follow the norms of a professional field. The reviewed literature, however, considers mainly coercive pressures (Mateo-Márquez et al., 2020). It is thus appropriate to investigate the following gaps in the institutional theory.

j. Do mimetic pressures influence the decision to assure carbon emissions?
k. Do normative pressures influence the decision to assure carbon emissions?

5.1.7 Contextual studies

The review shows that many studies are conducted in developed countries, however, this is problematic because developing and emerging countries have different institutional contexts hence, the findings may not apply to these contexts, hence, important for scholarship, to study about carbon assurance in developing and emerging countries. Future studies should investigate,

l. What drives the adoption of carbon assurance in developing and emerging countries?
m. What are the challenges of assuring carbon emissions in developing countries?

Further still, carbon assurance studies focus on large, listed firms, reporting to the carbon disclosure project, it would grow scholarship when different contexts such as, small sized, unlisted firms, that report carbon performance in annual, sustainability reports or company websites are examined, to assess how the findings compare with the former. Based on that, it is important to examine.

n. Does a low exposure to carbon risk, drive small sized firms to assure carbon disclosures?
o. Do unlisted firms assure their carbon emissions disclosures?
p. Are small and medium firms, subjected to less public scrutiny and media exposure incentivised to purchase carbon assurance?

5.2 Limitations

The reviewer single handedly coded, categorised, and abstracted themes from the data hence, the structured literature review did not benefit from a peer review nor inter coder reliability, to authenticate the accuracy of the coding process, and conceptualised themes.

Mindful that this was a single individual project, the review may have subjectively included and excluded articles, given the absence of a peer debriefer. Further still, errors may have occurred during data abstraction given the absence of data assessors which could impact on study findings. The choice of search keywords used to identify the review sample could have excluded or limited relevant articles, given the challenge surrounding the conceptualisation of carbon assurance.

5.3 Conclusion

The structured literature review overviewed the approaches, emerging themes, and theoretical underpinnings of carbon assurance to guide future studies. The aims have been accomplished by reviewing 52 relevant articles sourced from accounting, business, and management fields.

The review has shown that carbon assurance is not extensively defined and of the four minimally discussed carbon assurance approaches, greenhouse gas assurance is the most studied approach. Moreover, all approaches are not explicitly defined in literature, nor are the antecedents, process, outcomes, and challenges of the approaches thoroughly explored.

A synthesis of review findings formed three carbon assurance themes, namely, antecedents, outcomes, and challenges which gave an overview of the research field. Carbon assurance is driven by both external and internal factors. Climate change is the most influential external driver. Increasing effects of global warming have created a need for carbon information, to assess business risks which has consequently culminated into increased carbon disclosures. The need

for carbon assurance arises from the lack of trust attached to voluntary disclosure of carbon information, hence, carbon assurance is seen as a credibility enhancer for greenhouse gas statements. Institutionalisation of carbon institutions like the emission trading schemes has also equally exerted external pressure on firms as the contributors to greenhouse gas emissions.

Internally, large firms, high leverage and high carbon risk firms are also driven to assure their carbon emissions to minimise legitimacy threats. Carbon assurance is relevant in today's business as it improves the integrity of emissions statements, the credibility of disclosed carbon information and firm value.

The assurance of carbon emissions is however, still forming and not immune to challenges. The carbon assurance market is still voluntary, unregulated with a diversity of assurance standards, is highly competitive and susceptible to greenwashing, and is affected by the ineffective measurement and infrequent reporting of greenhouse gas emissions, whose information is an input in the carbon assurance process. It is paramount to devise strategies to resolve these challenges for scholarship and practice to thrive.

The theorising in carbon assurance is limited and focused on applying pre-existing theories to understand the phenomenon, there is hence a need for a new unified integration of theories to better understand carbon assurance.

To crown it all, the review has identified seven future research areas which include the need to redefine carbon assurance, the need for one unified carbon assurance name, the need to carry out an in-depth exploration of the carbon assurance approaches, as well as examine more drivers and outcomes of carbon assurance, resolve the challenges facing carbon assurance, as well as develop an integrated carbon assurance theory, research within other context to overcome the scantiness in literature.

This review gives valuable insights to both accounting and non- accounting practitioners about avenues of improving carbon assurance and management practices. Policy makers are also guided on the best policies of improving greenhouse gas assurance standards and the urgent need to mandate carbon assurance given the shortfalls of carbon disclosure, and lastly but not least, the review offers scholars new to the carbon assurance field, a starter pack of the current themes and the unexplored research areas worth investigating.

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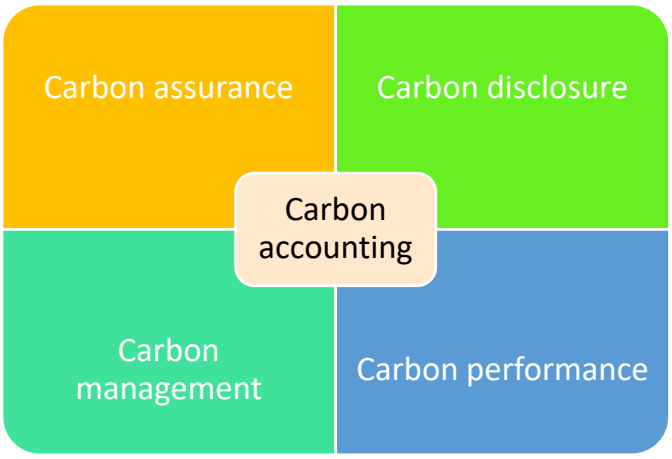
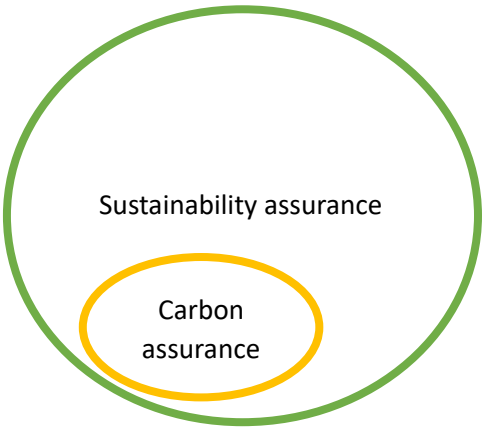
APPENDICES

Appendix 1: Research streams in carbon accounting





Appendix 2: List of keywords

Climate-change keywords	**Accounting, Business, Management-related keywords**	**Keyword combination**
"Greenhouse-gas"	"assurance"	"Greenhouse gas assurance audit"
"Greenhouse-gas emissions"	"assurance"	"Greenhouse gas emissions assurance"
"Carbon"	"assurance"	"Carbon assurance audit"
"Global warming"	"assurance"	"Global warming assurance"
"Non-financial"	"assurance"	"Non-financial assurance"
"Climate-change"	"assurance"	"Climate- change assurance"
"Climate-change"	"auditing"	"Climate- change auditing"
"GHG emissions"	"assurance"	"GHG assurance"
"GHG"	"audit"	"GHG audit"
"Emissions"	"assurance"	"Emissions assurance"
"Carbon dioxide"	"assurance"	"Carbon dioxide assurance"
"CO2"	"assurance"	"CO2 assurance"
"Carbon emissions"	"assurance"	"Carbon emissions assurance"
"CSR"	"assurance"	"CSR assurance"
"Carbon"	"auditing"	"Carbon auditing"

Source: He et al., 2022

Appendix 3: Search form

Stage	**Selection criteria**	**Excluded articles**					**Included articles**				
		Scopus	**Emerald Insight**	**Science direct**	**Google scholar**	Total	**Scopus**	**Emerald Insight**	**Science direct**	**Google scholar**	Total
1.	Initial search results						34	2000	27,799	2,820	32,653
2.	Publication years (2007-2023)	3	1,500	5,352	120	6,975	31	500	22,447	2,700	25,678
3.	Subject area (accounting, business, economics, finance, and management)	20	-	21,929	-	21,949	11	500	518	2700	3,729
4.	Document type (research articles, conference papers)	2	-	-	-	2	9	500	518	2700	3,727
5.	Publication stage (final)	1	-	-	-	1	8	500	518	2700	3,726
6.	Language (English)	0	-	1	-	1	8	500	517	2700	3,725
7.	Source/publication title	0	484	421	-	905	8	16	96	2700	2,820
8.	Carbon assurance focus	1	2	93	2,653	2,749	7	14	3	47	71
9.	Duplicates	-	4	1	14	19	7	10	2	33	52
	Articles left										**52**

Appendix 4: Title, abstract, and keywords form

No.	Author	Title selection	Abstract selection	Keywords selection	Key words	Decision	Reason
		Does the title include the relevant keywords?	Does the abstract include relevant keywords?	Are the keywords relevant?			
					SCOPUS		
1.	Mahmoudian et al. (2023)	Yes	Yes	Yes	GHG reduction projects Assurance GHG performance	Proceed to evaluation form	Article meets all criteria
2.	Fan et al. 2021	Yes	Yes	Yes	Independent carbon assurance GHG emissions	Proceed to evaluation form	Article meets all criteria
3.	Ekasingh et al. (2019)	Yes	Yes	Yes	GHG assurance Multidisciplinary team Team effectiveness	Proceed to evaluation form	Article meets all criteria
4.	Momim et al. (2017)	Yes	No	Yes	Greenhouse gas Legitimacy theory Carbon emissions	Proceed to evaluation form	Article meets 2 of the criteria
5.	Green & Taylor (2013).	Yes	Yes	Yes	Assurance Assurance quality Audit quality GHG assurance	Proceed to evaluation form	Article meets all criteria
6.	Martinov - Bennie (2012)	Yes	Yes	Yes	Greenhouse gas emissions GHG reporting Governance Auditing assurance	Proceed to evaluation form	Article meets all criteria
7.	Green & Li (2012)	Yes	Yes	Yes	Expectations gap Greenhouse gas emissions assurance Carbon assurance	Proceed to evaluation form	Article meets all criteria
8.	Olson (2010)	Yes	Yes	Yes	Global warming Auditing Financial reporting	Proceed to evaluation form.	Article meets all criteria

No.	Author	Title selection	Abstract selection	Keywords selection	Key words	Decision	Reason
		Does the title include the relevant keywords?	Does the abstract include relevant keywords?	Are the keywords relevant?			
					EMERALD INSIGHT		
1.	Datt et al. (2022)	Yes	Yes	Yes	Assurance Audit & assurance services firm Carbon emission disclosures	Proceed to evaluation form	Article meets all criteria
2.	Green, & Taylor (2013)	Yes	Yes	Yes	Assurance Sustainability reporting Environmental reporting Auditor choice Greenhouse gas emissions	Proceed to evaluation form	Article meets all criteria
3.	Datt et al. (2019)	Yes	Yes	Yes	Carbon emissions Legitimacy theory Carbon assurance	Proceed to evaluation form	Article meets all criteria
4.	Dutta, P., & Dutta, A. (2021)	Yes	Yes	Yes	External assurance Climate change disclosure	Proceed to evaluation form	Article meets all criteria
5.	Rohani et al. (2023)	Yes	Yes	Yes	Carbon performance Levels of carbon assurance	Proceed to evaluation form	Article meets all criteria
6.	Milne & Grubnic (2011)	Yes	No	Yes	Climate change accounting GHG emissions Carbon accounting	Proceed to evaluation form	Article meets 2
7.	Lodhia & Martin (2012)	Yes	No	Yes	Carbon Greenhouse Emissions	Proceed to evaluation form	Article meets 2
8.	Hsiao et al. (2022)	No	No	No	Sustainability assurance	Do not Proceed	Does not meet any
9.	Mia et al. (2019)	Yes	Yes	Yes	Disclosure Carbon emissions	Proceed to evaluation form	Article meets all criteria
10.	Sheldon & Jenkins (2020)	Yes	Yes	Yes	Reasonable assurance Limited assurance	Proceed to evaluation form	Article meets all criteria
11.	Lodhia (2011)	No	No	Yes	Carbon Energy management	Do not proceed	Article meets 1

12.	Pitrakkos & Maroun (2020).	Yes	Yes	Yes	Content analysis Legitimacy Integrated reporting Carbon reporting	Proceed to evaluation form	Article meets all criteria
13.	Stuart et al. (2022)	No	No	No	CSR assurance CSR disclosure	Do not proceed	does not meet any
14.	Soh & Martinov - Bennie (2015)	Yes	No	No	Social and governance assurance	Do not Proceed	Article meets 1
15.	Maroun (2019)	No	No	Yes	Integrated reporting Audit/ assurance	Do not Proceed	Article meets 1
16.	Prinsloo & Maroun (2020)	No	Yes	No	Integrated reporting Combined assurance	Do not Proceed	Article meets 1
17.	Comyns & Figge (2015)	Yes	No	Yes	Greenhouse gas	Proceed	Article meets 2
18.	Jones et al. (2016)	No	No	Yes	Materiality External assurance	Do not Proceed	Article meets 1
19.	Abrams et al. (2021)	No	No	No	Sustainability Corporate social responsibility	Do not Proceed	Does not meet any
20.	Young (2010)	No	No	No	Global warming accounting	Do not Proceed	Does not meet any
21.	Kazemian et al., (2022)	No	Yes	Yes	Carbon emitting industries	Proceed	Article meets 2
22.	Borghei et al (2016)	No	No	Yes	GHG emissions Carbon disclosures	Do not Proceed	Article meets 1
23.	Simnett (2012)	No	No	No	Sustainability Assurance standards	Do not Proceed	Does not meet any
24.	Rosa et al. (2021)	No	No	Yes	Non-financial information Greenhouse gases	Do not Proceed	Article meets 1
25.	Burritt & Schaltegger (2012)	No	No	No	Sustainability accounting Sustainability development	Do not Proceed	Does not meet any
26.	Mishra et al., (2022)	No	No	Yes	Carbon emission Carbon neutrality	Do not Proceed	Article meets 1

27.	Hostut & van het Hof (2020)	No	No	Yes	Greenhouse gas emissions Sustainability reporting	Do not Proceed	Article meets 1
28.	Ackers & Eccles (2015)	No	No	Yes	CSR Assurance Assurance provider	Do not Proceed	Article meets 1
29.	Rezaee (2016)	No	No	No	Sustainability assurance Sustainability performance	Do not Proceed	Does not meet any
30.	Gibassier & Schaltegger (2015)	No	No	No	Carbon accounting Management accounting	Do not Proceed	Does not meet any
31.	Rankin et al. (2011)	No	No	Yes	GHG emission disclosure carbon	Do not Proceed	Article meets 1
32.	Dutta (2019)	No	No	Yes	Sustainability reports Voluntary External assurance	Do not Proceed	Article meets 1
33.	Ramanathan & Isaksson (2022)	No	No	No	Sustainability Sustainability development	Do not Proceed	Does not meet any
34.	Boiral et al. (2019)	No	No	No	Sustainability reporting assurance	Do not Proceed	Does not meet any
35.	Liu & Wu (2023)	No	No	No	Green finance Green bond Sustainability disclosure	Do not Proceed	Does not meet any
36.	Cordove et al (2021)	No	No	No		Do not Proceed	Does not meet any
37.	Guthrie et al (2020)	No	No	No		Do not Proceed	Does not meet any
38.	Abernathy et al (2017)	No	No	No		Do not Proceed	Does not meet any
39.	Yang & Farley (2016)	No	No	No		Do not Proceed	Does not meet any
40.	Tyson & adams	No	No	No		Do not Proceed	Does not meet any

41.	Mateo-Márquez et al. (2020)	Yes	Yes	No	Climate change regulation	Proceed	Article meets 2 of the 3
42.	Chithambo & Tauringana (2014)	Yes	No	Yes	Greenhouse gases	Proceed	Article meets 2 of the 3
					SCIENCE DIRECT		
1.	Comyns (2018)	Yes	No	Yes	Climate change reporting Sustainability reporting	Proceed	Article meets 2 of the 3
2.	Tauringana & Chithambo (2015)	Yes	No	Yes	Greenhouse gas disclosure	Proceed	Article meets 2 of the 3
No.	Author(s)	Title selection	Abstract selection	Keywords selection	Key words	Decision	Reason
		Does the article's title include the specified keywords for the study?	Does the article's abstract include the specified keywords for the study?	Do the article's keywords include the study's specified keywords?			
					GOOGLE SCHOLAR		
1.	Huggins et al. (2011)	Yes	Yes	Yes	Greenhouse gas assurance	Proceed	Article meets all criteria
2.	Green & Taylor (2017).	Yes	Yes	Yes	Assurance Audit choice Greenhouse gas emissions	Proceed	Article meets all criteria
3.	Zhou et al. (2016)	Yes	Yes	Yes	Greenhouse gas assurance	Proceed	Article meets all criteria
4.	Green & Zhou (2013)	Yes	Yes	No	Not included	Proceed	Article meets 2 of the 3
5.	Simnet et al. (2010)	Yes	Yes	Yes	Greenhouse gas emissions assurance	Proceed	Article meets all criteria

6.	Simnett & Nugent (2007)	Yes	Yes	No	Not included	Proceed	Article meets 2 of the 3
7.	Chatterje e (2012)	Yes	Yes	Yes	Independent external assurance provider	Proceed	Article meets all criteria
8.	Simnett et al. (2009)	Yes	Yes	No	Not included	Proceed	Article meets 2 of the 3
9.	Busch et al. (2023)	Yes	Yes	No	Not included	Proceed	Article meets 2 of the 3
10.	Simic et al. (2023)	Yes	Yes	Yes	Voluntary carbon assurance	Proceed	Article meets all criteria
11.	Saha et al. (2021)	Yes	Yes	Yes		Proceed	Article meets all criteria
12.	Kim et al. (2016)	Yes	Yes	Yes	Greenhouse gas (GHG) assurance	Proceed	Article meets all criteria
13.	Zhou (2022)	Yes	Yes	No	Not included	Proceed	Article meets 2 of the 3
14.	Martinov -Bennie & Hoffman (2012)	Yes	Yes	No	Not included	Proceed	Article meets 2 of the 3
15.	Luo et al. (2023)	Yes	Yes	Yes	Carbon accounting Carbon assurance	Proceed	Article meets all criteria
16.	Ratnatun ga (2007)	Yes	Yes	Yes	Carbon auditing Carbon auditing and assurance	Proceed	Article meets all criteria
17.	Tang & Demeritt (2018)	Yes	Yes	Yes	Climate change Emissions	Proceed	Article meets all criteria
18.	Ascui (2014)	No	Yes	-	Not included	Proceed	It's a review paper in carbon accounting
19.	Bui et al. (2021)	Yes	Yes	Yes	Sustainability Carbon assurance	Proceed	Article meets all criteria
20.	Datt et al. (2020)	Yes	Yes	Yes	Assurance provider Climate change	Proceed	Article meets all criteria
21.	Datt et al. (2018)	Yes	Yes	Yes	Voluntary carbon assurance Carbon governance	Proceed	Article meets all criteria
22.	Green et al. (2009)	Yes	Yes	-	Not provided	Proceed	Article meets 2 of the 3
23.							

Appendix 5: Evaluation form- a measure of precision (Linares- Espinos et al., 2018).

No.	Article	English	Concepts	Journal	Stage	Interd.	Journal Rank	Year	Empirical	Decision	Reason
1.	Bui et al. 2021	Yes	Yes	Yes	Final	Yes	Yes	Yes	Yes	Proceed	Article meets all criteria
2.	Datt et al. 2022	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
3.	Datt et al. 2020	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
4.	Datt et al. 2019	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
5.	Datt et al. 2018	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
6.	Dutta P & Dutta A 2021	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
7.	Ekasingh et al 2019	Yes	Yes	Yes	Final	Yes	Yes	Yes	Yes	Proceed	Article meets all criteria
8.	Fan et al 2021	Yes	Yes	Yes	Final	Yes	Yes	Yes	Yes	Proceed	Article meets all criteria
9.	Hassan et al 2020	Yes	No	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
10.	He et al 2022	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
11.	Kazemian et al 2022	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3

12.	Luo et al. 2023	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
13.	Mahmoudian et al 2023	Yes	Yes	Yes	Final	Yes	Yes	Yes	Yes	Proceed	Article meets all criteria
14.	Muslemani et al. 2021	Yes	No	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
15.	Ott & Schiemann 2023	Yes	No	Yes	Final	Yes	Yes	Yes	Yes	Proceed	Article meets all criteria
16.	Pitrakkos & Maroun 2020	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
17.	Robani et al. 2023	Yes	Yes	Yes	Final	Yes	No	Yes	Yes	Do not proceed	The journal rank is below 3
18.	Shrestha et al. 2023	Yes	No	Yes	Final	Yes	Yes	Yes	Yes	Proceed	Article meets all criteria
19.	Sobhan et al 2018	Yes	No	Yes	Final	No	No	Yes	Yes	Do not proceed	The journal rank is below 3

Appendix 6: Google scholar citation counts conducted on 21st /September/ 2023

No.	Author	Title of paper	Citation counts
1.	Ascui 2014	A review of carbon accounting in the social and environmental accounting literature: What can it contribute to the debate?	98
2.	Bui et al. 2021	Climate change mitigation: Carbon assurance and reporting	16
3.	Busch et al. 2023	Corporate Greenhouse Gas Emissions' Data and the Urgent Need for a Science-Led Just Transition: Introduction to a Thematic Symposium.	4
4.	Chatterjee 2012	Assurance of corporate greenhouse gas disclosures in the mining and crude oil production sector: a comparative inter-national study	11
5.	Chithambo & Tauringana 2014	Company specific determinants of greenhouse gases disclosures.	89
6.	Comyns 2018	Climate change reporting and multinational companies: Insights from institutional theory and international business	67
7.	Comyns & Figge 2015	Greenhouse gas reporting quality in the oil and gas industry: A longitudinal study using the typology of "search", "experience" and "credence" information.	129
8.	Datt et al. 2020	Corporate choice of providers of voluntary carbon assurance	26
9.	Datt et al. 2019	The impact of legitimacy threat on the choice of external carbon assurance, Evidence from the US	38
10.	Datt et al. 2018	An international study of the determinants of Voluntary carbon assurance	57
11.	Dutta P. & Dutta A. 2021	Impact of External assurance on corporate climate change disclosures: new evidence from Finland	17
12.	Ekasingh et al. 2019	The effect of diversity and the mediating role of elaboration on Multidisciplinary Greenhouse gas assurance team effectiveness	13
13.	Fan et al. 2021	An international study of carbon information asymmetry an independent carbon assurance	33
14.	Green et al. 2009	The expertise required for greenhouse gas assurance engagements: lessons to be learned from existing schemes and standards.	14
15.	Green & Li 2012	Evidence of an expectation gap for greenhouse gas emissions assurance.	106
16.	Green & Taylor 2013	Factors that influence perceptions of greenhouse gas assurance provider quality	42
17.	Green & Zhou 2013	An international examination of assurance practices on carbon emissions disclosures.	49
18.	Hay et al. 2023	Comments on the AFAANZ Auditing and Assurance Standards Committee on the Proposed standard on Assurance Engagements over GHG Emissions Disclosure	-
19.	He et al. 2022	Corporate carbon accounting: a literature review of carbon accounting research from the Kyoto Protocol to the Paris Agreement	88
20.	Huggins et al. 2011	The competitive market for assurance engagements on greenhouse gas statements: Is there a role for assurors from the accounting profession?	152
22.	Kazemian et al. 2022	Carbon management accounting (CMA) practices in Australia's high carbon emissions industries	5
22.	Kim et al. 2016	Biased evidence processing by multidisciplinary greenhouse gas assurance teams.	19
23.	Knechel 2021	The future of assurance in capital markets: Reclaiming the economic imperative of the Auditing profession	39
24.	Ioannou et al. 2016	The effect of target difficulty on target completion: the case of reducing carbon emissions	175
25.	Lodhia & Martin 2012	Stakeholders' responses to the national greenhouse and energy reporting Act	65
26.	Luo et al. 2023	Corporate carbon assurance and the quality of carbon disclosure	1
27.	Mahmoudian et al. 2023	Does cost of debt reflect the value of quality greenhouse gas emissions reductions efforts and disclosure	1
28.	Mateo-Márquez et al. 2020	Countries' regulatory context and voluntary carbon disclosures	31
29.	Martinov-Bennie 2012	Greenhouse gas emissions reporting and assurance: reflections on the current state	30

30.	Martinov-Bennie & Hoffman 2012	Greenhouse gas and energy audits under the newly legislated Australian audit determination: perceptions of initial impact.	25
31.	Matsumura et al. 2014	Firm- value effects of carbon emissions and carbon disclosures	1167
32.	Mia et al. 2019	Greenhouse gas emissions disclosure by cities: the expectation gap.	31
33.	Moroney et al. 2011	Evidence of assurance enhancing the quality of voluntary environmental disclosures: an empirical analysis	412
34.	Olson 2010	Challenges and opportunities from greenhouse gas emissions reporting and independent auditing.	70
35.	Pitrakkos & Maroun 2020	Evaluating the quality of carbon disclosures	48
36.	Ratnatunga 2007	An inconvenient truth about accounting	54
37.	Rohani et al. 2023	Corporate incentives for obtaining higher levels of carbon assurance: seeking legitimacy or improving performance?	2
38.	Ryan & Tiller 2022	A recent survey of GHG emissions reporting and assurance	6
39.	Simic et al. 2023	Compensation and carbon assurance: Evidence from the UK	-
40.	Simnett et al. 2009	Developing an international assurance standard on greenhouse gas statements.	170
41.	Simnett et al. 2010	Are greenhouse gas assurance engagements a natural domain of the auditing profession?	12
42.	Simnett & Nugent 2007	Developing an assurance standard for carbon emissions disclosures.	65
43.	Simnett 2007	A critique of the international auditing and assurance standards board	14
44.	Tang & Luo2014	Carbon management systems and carbon mitigation	178
45.	Tang 2019	Institutional influence, Transition management and the demand for carbon auditing: The Chinese experience	22
46.	Tang & Demerritt 2018	Climate change and mandatory carbon reporting: impacts on Business Process and performance	111
47.	Tauringana & Chithambo 2015	The effect of DEFRA guidance on greenhouse gas disclosure.	230
48.	Trotman & Trotman 2015	Internal audit's role in GHG emissions and energy reporting: Evidence from audit committees, senior accountants, and internal auditors	152
49.	Vera-Munoz et al. 2020	Communicating assurance using practitioner-customised procedures: an experiment and emerging research opportunities	9
50.	Xu & Andrew 2021	Competing for the leading role: Trials in categorizing greenhouse and energy auditors.	3
51.	Zhou et al. 2022	Reporting and Assurance of Climate-Related and Other Sustainability Information: A Review of Research and Practice	12
52.	Zhou et al. 2016	Assuring a new market: The interplay between country-level and company-level factors on the demand for greenhouse gas (GHG) information assurance and the choice of assurance provider.	79

Appendix 7: Evaluation form- a measure of sensitivity (Linares- Espinos et al., 2018).

No.	Author	Written in English?	Published in academic journal?	Final or in press?	Published in accounting, business, economics, finance, and management journals?	Is journal quality good?	Is the year of publication within the specified inclusion criteria?	Empirical article?	Are concepts discussed relevant?	Decision	Reason
1.	Ascui 2014	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
2.	Bui et al. 2021	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
3.	Busch et al. 2023	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
4.	Chatterjee 2012	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
5.	Chithambo & Tauringana 2014	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
6.	Comyns 2018	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
7.	Comyns & Figge 2015	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
8.	Datt et al. 2020	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
9.	Datt et al. 2019	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
10	Datt et al. 2018	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
11.	Dutta P. & Dutta A. 2021	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
12.	Ekasingh et al. 2019	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
13.	Fan et al. 2021	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
14.	Green et al. 2009	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria

15.	Green & Li 2012	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
16.	Green & Taylor 2013	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
17.	Green & Zhou 2013	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
18.	Hay et al. 2023	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
19.	He et al. 2022	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
20.	Huggins et al. 2011	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
21.	Kazemian et al. 2022	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
22.	Kim et al. 2016	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
23.	Knechel 2021	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
24.	Ioannou et al. 2016	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
25.	Lodhia & Martin 2012	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
26.	Luo et al. 2023	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
27.	Mahmoudian et al. 2023	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
28.	Mateo-Márquez et al. 2020	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
29.	Martinov-Bennie 2012	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
30.	Martinov-Bennie & Hoffman 2012	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
31.	Matsumura et al. 2014	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria

32.	Mia et al. 2019	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
33.	Moroney et al. 2011	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
34.	Olson 2010	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
35.	Pitrakkos & Maroun 2020	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
36.	Ratnatunga 2007	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
37.	Rohani et al. 2023	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
38.	Ryan & Tiller 2022	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
39.	Simic et al. 2023	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
40.	Simnett et al. 2009	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
41.	Simnett et al. 2010	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
42.	Simnett & Nugent 2007	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
43.	Simnett 2007	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
44.	Tang & Luo2014	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
45.	Tang 2019	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
46.	Tang & Demerrit 2018	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
47.	Tauringana & Chithambo 2015	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
48.	Trotman & Trotman 2015	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria

49.	Vera-Munoz et al. 2020	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
50.	Xu & Andrew 2021	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
51.	Zhou et al. 2022	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria
52.	Zhou et al. 2016	Yes	Yes	Final stage	Yes	Yes	Yes	Yes	Yes	Proceed to study eligibility form	Article meets all criteria

Appendix 8: Data extraction form: Biographic information

No.	Name of author	Year of publication	Title	Journal name	Journal rank (AJG 2021 and ABDC 2022)	Discipline	Purpose of the paper
1.	Ascui	2014	Carbon accounting review	Social and Environmental Accountability Journal	1B	Accounting	Understand how carbon accounting has been studied in social and environmental accounting literature.
2.	Bui et al.	2021	Effect of carbon assurance on quality of reporting	Business strategy and the Environment	3A	Environment	Study relationship between earnings management and carbon assurance
3.	Busch et al.	2023	Greenhouse gas emissions' data and the role of science in the just transition	Journal of Business Ethics	3A	Ethics	
4.	Chatterjee	2012	Greenhouse gas disclosures assurance	Journal of Asia Pacific Centre for Environmental Accountability	unknown	unknown	What drives verification of GHG emissions? What drives production of GHG reports? What drives the choice of assurance providers?
5.	Chithambo and Taurigana	2014	Determinants of greenhouse gas disclosures	Journal of Applied Accounting Research	2B	Accounting	Investigate company drivers of GHG disclosures
6.	Comyns & Figge	2015	Quality of greenhouse gas reporting	Accounting, Auditing & Accountability Journal	3A*	Accounting	Investigate the evolution of the quality GHG reporting and whether the type of information drives the evolution
7.	Comyns	2018	Multinational companies and climate change reporting	Accounting Forum	3B	Accounting	To develop a theoretical framework for the GHG reporting practices of MNCs
8.	Datt et al.	2020	Choice of carbon assurance providers	International Journal of Auditing	2A	Accounting	Investigate the drivers for the choice of assurance providers
9.	Datt et al.	2019	Legitimacy threat effect on external carbon assurance	Accounting Research Journal	2B	Accounting	Examine association between legitimacy threat and incentive to obtain external carbon assurance
10.	Datt et al.	2018	Determinants of carbon assurance	Journal of International Accounting Research	2A	Accounting	Examine drivers for the adoption of external carbon assurance
11.	Dutta P. & Dutta A.	2021	External assurance impact on climate change disclosures	Journal of Applied Accounting Research	2B	Accounting	Examine impact of external assurance on climate change disclosures
12.	Ekasingh et al.	2019	Diversity effect and the mediating role of elaboration on greenhouse gas assurance effectiveness	Behavioral Research in Accounting	3A	Accounting	Examine effect of diversity in education and elaboration among team members on multidisciplinary GHG assurance team effectiveness
13.	Fan et al	2021	Carbon information asymmetry effect on carbon assurance	The British Accounting Review	3A*	Accounting	Examine the influence of information asymmetry on the adoption of carbon assurance
14.	Green & Li	2012	Greenhouse gas emissions assurance expectation gap	Accounting, Auditing & Accountability Journal	3A*	Accounting	Examine the existence of an expectation gap among several stakeholders in the assurance of GHG emissions
15.	Green & Taylor	2013	Influencing factors for quality of greenhouse gas assurance provider	International Journal of Auditing	2A	Accounting	Examine the factors that influence the perceptions of the quality of GHG assurance provider

16.	Green & Zhou	2013	Assurance practices of carbon disclosures	Australian Accounting Review	2B	Accounting	Examine assurance practices for carbon emissions disclosures of international companies in 43 countries
17.	Green et al.	2009	Greenhouse gas assurance expertise	Environment	unknown	Unknown	Examine the expertise for GHG assurance engagements
18.	Hay et al.	2023	Comments on the Proposed standard on greenhouse gas emissions Assurance	Accounting and Finance	2A	Accounting	To present a technical note for the comments of AFAANZ auditing and assurance standards committee
19.	He et al	2022	Carbon accounting literature review	Accounting and Finance	2A	Accounting	To give a description of the development of carbon accounting and gaps in knowledge
20.	Huggins et al.	2011	Greenhouse gas statements assurance market	Current issues in Auditing	2B	Accounting	To examine the drivers for the choice of assurance providers Discuss characteristic of the assurance engagement
21.	Ioannou et al.	2016	Target difficulty effect on target completion	The Accounting review	4*A*	Accounting	To examine how target difficulty affects the degree of target completion in non-financial performance
22.	Kazemian et al	2022	Australia's carbon management accounting practices	Sustainability Accounting, Management and Policy Journal	2B	Accounting	To examine the carbon management practices of Australian's high carbon emitting companies
23.	Kim et al.	2016	Multidisciplinary greenhouse gas assurance teams processing of biased evidence	Auditing: A journal of practice and Theory	3A*	Accounting	To examine auditors' response to discipline specific expertise of GHG assurance teams
24.	Knechel	2021	The future of assurance in capital markets: reclaiming the economic imperative of the auditing profession	Accounting horizons	3A	Accounting	To discuss the future of assurance in the capital market
25.	Lodhia & Martin	2012	Stakeholders' responses to the national greenhouse and energy reporting Act	Accounting, Auditing, and Accountability Journal	3A*	Accounting	To explore stakeholders' submissions to the NGER
26.	Luo et al.	2023	Corporate carbon assurance and the quality of carbon disclosure	Accounting and Finance	2A	Accounting	To explore the relationship between carbon disclosure and carbon assurance
27.	Mahmoudian et al	2023	Does cost of debt reflect the value of quality greenhouse gas emissions reductions efforts and disclosure	Journal of International Accounting, Auditing and Taxation	3B	Accounting	To examine whether carbon management practices of North American companies influence the cost of debt in relation to carbon emissions.
28.	Mateo-Márquez et al.	2020	Countries' regulatory context and voluntary carbon disclosures	Sustainability Accounting, Management and Policy Journal	2B	Accounting	To examine the influence of climate related regulation on carbon reporting
29.	Martinov-Bennie	2012	Greenhouse gas emissions reporting and assurance: reflections on the current state	Sustainability Accounting, Management and Policy Journal	2B	Accounting	To examine the challenges and opportunities of GHG reporting and assurance from an Australian context.
30.	Martinov-Bennie and Hoffman	2012	Greenhouse gas and energy audits under the newly legislated Australian audit determination: perception of initial impact	Australian Accounting Review	2B	Accounting	To explore the impact of GHG, and energy audits in Australia.
31.	Matsumura et al	2014	Firm- value effects of carbon emissions and carbon disclosures	The Accounting review	4*A*	Accounting	To examine the effect of carbon emissions and disclosure of carbon emissions on firm value

32.	Moroney et al.	2011	Evidence of assurance enhancing the quality of voluntary environmental disclosures: an empirical analysis	Accounting and Finance	2A	Accounting	To examine the effect of independent assurance on the quality of environmental disclosures
33.	Mia et al	2019	Greenhouse gas emissions disclosures by cities: the expectation gap	Sustainability Accounting, Management and Policy Journal	2B	Accounting	To explore the quality of cities' GHG disclosures in the CDP and compare it with users' expectation
34.	Olson	2010	Challenges and opportunities from greenhouse gas emissions reporting and independent auditing	Managerial Auditing Journal	2A	Accounting	To identify and discuss the challenges and opportunities associated with GHG emissions reporting and assurance
35.	Pitrakkos & Maroun	2020	Evaluating the quality of carbon disclosures	Sustainability Accounting, Management and Policy Journal	2B	Accounting	To examine the differences in quality and quantity of GHG disclosures among companies with large and small carbon footprint
36.	Ratnatunga	2007	An inconvenient truth about accounting	Journal of Applied Management Accounting research	unknown	unknown	To examine the impact of the Kyoto protocol and whether the accounting professions is ready for the carbon trading legislation challenges.
37.	Rohani et al	2023	Corporate incentives for obtaining higher levels of carbon assurance: seeking legitimacy or improving performance?	Journal of Applied Accounting Research	2B	Accounting	To examine the incentives for obtaining a higher level of carbon assurance
38.	Ryan & Tiller	2022	A recent survey of GHG emissions reporting and assurance	Australian Accounting Review	2B	Accounting	To understand New Zealand's current market practices of GHG emissions reporting.
39.	Simic et al	2023	Compensation and carbon assurance: Evidence from the UK	International Journal of Auditing	2A	Accounting	To examine whether compensation drives carbon assurance
40.	Simnett	2007	A critique of the international auditing and assurance standards board	Australian Accounting Review	2B	Accounting	To examine the developments of the IAASB and their impact of Australia
41.	Simnett and Nugent	2007	Developing an assurance standard for carbon emissions disclosures	Current issues in Auditing	2B	Accounting	To examine the development of an assurance standard on carbon emissions disclosures.
42.	Simnett et al.	2010	Are greenhouse gas assurance engagements a natural domain of the auditing profession?	Current Issues in Auditing	2B	Accounting	To examine whether GHG assurance engagement are a natural domain of the auditing profession.
43.	Simnett et al.	2009	Developing an international assurance standard on greenhouse gas statements	Accounting horizons	3A	Accounting	To give an argument in support of the international standards on GHG emissions disclosures
44.	Tang and Luo	2014	Carbon management systems and carbon mitigation	Australian Accounting Review	2B	Accounting	To examine the implementation of the carbon management system by large Australian firms.
45.	Tang	2019	Institutional influence, transition management and the demand for carbon auditing: the Chinese experience	Australian Accounting Review	2B	Accounting	To examine the drivers of carbon auditing in China.
46.	Tang and Demeritt	2018	Climate change and mandatory carbon reporting impacts on Business Process and performance	Business strategy and the Environment	3A	Environment	To examine the purpose, practice, and impact of corporate social responsibility reporting
47.	Tauringana and Chithambo	2015	DEFRA guidance effect on greenhouse gas disclosure	The British Accounting Review	3A*	Accounting	To examine the effects of DEFRA on GHG disclosures
48.	Trotman and Trotman	2015	Role of an Internal Auditor in greenhouse gas emissions	Auditing: A journal of practice and Theory	3A*	Accounting	To examine the role of internal auditors in GHG disclosures

49.	Vera-Munoz et al.	2020	Communicating assurance	Auditing: A journal of practice and Theory	3A*	Accounting	To examine report users' confidence judgement for GHG assurance report
50.	Xu and Andrew	2020	Challenges in categorising greenhouse auditors	Critical perspectives on accounting	3A	Accounting	To examine Australian government's attempt to categorize GHG and energy auditors
51.	Zhou et al.	2022	A Review of Climate-Related and Other Sustainability Information	Australian Accounting Review	2B	Accounting	To provide a summary of the practices, drives and outcomes of disclosure and assurance of climate related and sustainability information.
52.	Zhou et al.	2016	Demand for greenhouse gas assurance and the choice of assurance provider	Auditing: A Journal of Practice & Theory	3A*	Accounting	To examine drivers of GHG assurance.

Appendix 9: Data extraction form: Detailed description of papers

No.	Name of author	Year	General research focus	Research setting	Continent
1.	Ascui	2014	Prior literature review		Multi- continental
2.	Bui et al.	2021	Outcome of carbon assurance	USA	North America
3.	Busch et al.	2023	Role of carbon assurance		Multi- continental
4.	Chatterjee	2012	Antecedents of carbon assurance GHG statements Supply of carbon assurance	Global 500	Multi- continental
5.	Chithambo and Taurigana	2014	Antecedents of GHG disclosures	UK	Europe
6.	Comyns & Figge	2015	Evolution of GHG reporting quality		Multi- continental
7.	Comyns	2018	Theoretical framework of MNCs' GHG reporting practices	Global 500	Multi- continental
8.	Datt et al	2020	Supply of carbon assurance		Multi- continental
9.	Datt et al	2019	Antecedents of carbon assurance	USA	North America
10.	Datt, Luo, Tang, and Mallik	2018	Antecedents of carbon assurance		Multi- continental
11.	Dutta P & Dutta A	2021	Outcome of carbon assurance	Finnish	Europe
12.	Ekasingh, Simnett, and Green	2019	Supply of carbon assurance	Australia	Oceania
13.	Fan et al	2021	Antecedents of carbon assurance		Multi- continental
14.	Green & Li	2012	Expectation gap	Australia	Oceania
15.	Green & Taylor	2013	Supply of carbon assurance	Australia	Oceania
16.	Green & Zhou	2013	Practices		Multi- continental
17.	Green et al.	2009	Assurance engagement		Multi- continental
18.	Hay et al	2023	Assurance standards	New Zealand	Oceania
19.	He et al	2022	Prior literature review		Multi- continental
20.	Huggins et al.	2011	Supply of carbon assurance		Multi- continental

			Assurance engagement		
21.	Kazemian et al	2022	Practices	Australia	Oceania
22.	Kim et al.	2016	Assurance engagement	Australia	Oceania
23.	Knechel	2021	Practices		Multi- continental
24.	Ioannou et al.	2016	Outcome of target difficulty		Multi- continental
25.	Lodhia & Martin	2012	Reporting act	Australia	Oceania
26.	Luo et al.	2023	Outcome of carbon assurance		Multi- continental
27.	Mahmoudian et al	2023	Practices	USA and Canada	North America
28.	Mateo-Márquez et al.	2020	Outcome of climate related regulation		Multi- continental
29.	Martinov-Bennie	2012	challenges and opportunities of GHG reporting and assurance		Oceania
30.	Martinov-Bennie and Hoffman	2012	Outcome of GHG, and energy assurance		Oceania
31.	Matsumura et al	2014	Outcome of carbon emissions and carbon disclosure		Multi- continental
32.	Moroney et al.	2011	Outcome of carbon assurance		Oceania
33.	Mia et al	2019	Quality of cities' GHG disclosures		Multi- continental
34.	Olson	2010	Challenges and opportunities of GHG emissions reporting and assurance		Multi- continental
35.	Pitrakkos & Maroun	2020	GHG disclosures	South Africa	Africa
36.	Ratnatunga	2007	Impact of the Kyoto protocol		Multi- continental
37.	Rohani et al	2023	Supply of carbon assurance	USA	North America
38.	Ryan & Tiller	2022	Practices	New Zealand	Oceania
39.	Simic et al	2023	Antecedent of carbon assurance	UK	Europe
40.	Simnett	2007	Assurance standards		Multi- continental
41.	Simnett and Nugent	2007	Assurance standards		Multi- continental
42.	Simnett et al.	2010	Assurance engagement		Multi- continental
43.	Simnett et al.	2009	Assurance standards		Multi- continental
44.	Tang and Luo	2014	Practices	China	Asia
45.	Tang	2019	Antecedents of carbon assurance	UK	Europe
46.	Tang and Demeritt	2018	Corporate social responsibility reporting	Australia	Oceania
47.	Tauringana and Chithambo	2015	Effects of DEFRA	London FTSE 350	Europe
48.	Trotman and Trotman	2015	GHG disclosures	Australia	Oceania
49.	Vera-Munoz et al.	2020	GHG statements	USA	North America
50.	Xu and Andrew	2020	Supply of carbon assurance	Australia	Oceania
51.	Zhou et al.	2022	Prior literature review		Multi- continental
52.	Zhou et al.	2016	Antecedent of carbon assurance	Australia	Oceania

Appendix 10: Data extraction form: Methodological information

No.	Author's name	Year of publication	Research methodology	Research methods	Key findings
1.	Ascui	2014	Qualitative	Literature review	Carbon accounting is gaining increasing attention, great research potential lies ahead
2.	Bui et al.	2021	Quantitative	Generalised method of moments	Quality of reports improve when carbon emissions are assured, but with diversity: gender
3.	Busch et al.	2023	Conceptual		Persistent challenges of quality of data
4.	Chatterjee	2012	Qualitative	Content analysis	There are prevailing gaps in data: SMEs and scope 3. Greenhouse gases should be better estimated. Improve quality of data in assurance
5.	Chithambo and Taurigana	2014	Quantitative	OLS	The size of a firm, among other factors influence disclosure of greenhouse gas emissions
6.	Comyns & Figge	2015	Mixed methods	Qualitative and quantitative methods	Reporting of greenhouse gas emissions has increased, due to climate change, guidelines. Report quality has not consequently improved.
7.	Comyns	2018	Qualitative	Case study 3 cases	Pressure from institutions influence practices of reporting in MNCs.
8.	Datt et al.	2020	Quantitative	Logit and probit regression	Greater inclination towards accounting assuror if firms want to minimize legitimacy concerns. Those who seek to manage their carbon emissions, approach other professions besides accountants.
9.	Datt et al.	2019	Quantitative	GLS logit regression	High carbon firms and large sized firms assure to reduce legitimacy concerns
10.	Datt et al.	2018	Quantitative	Logit regression	High risk from carbon emissions, initiatives to reduce carbon, committees focused on environment issues, incentives to reduce carbon emissions, reporting of carbon drive decisions to assure
11.	Dutta, P. & Dutta, A.	2021	Quantitative	Regression	Assuring carbon emissions improve disclosures on climate-change
12.	Ekasingh et al.	2019	Quantitative	Univariate analysis and SEM	Effectiveness of teams is improved when members' perceptive are elaborated.
13.	Fan et al.	2021	Quantitative	Logistic regression	Assuring carbon emission reduces information gaps
14.	Green & Li	2012	Quantitative	Experiment	There are gaps in stakeholders' expectations regarding assuring carbon emissions.
15.	Green & Taylor	2013	Quantitative	Survey	Assuror quality perceptions is influenced by assurance integrity among other factors
16.	Green & Zhou	2013	Quantitative	Descriptive	Firms in European countries and high emitting industries mainly assure carbon emissions.
17.	Green et al.	2009	Conceptual		Greenhouse gas assurance requires controlling the level of quality among assurors
18.	Hay et al.	2023	Conceptual		Submitting a note to the assurance board
19.	He et al.	2022	Qualitative	Literature review	Carbon accounting has 4 streams.
20.	Huggins et al.	2011	Conceptual		High competition in the Greenhouse gas assurance market, equal dominance of assurors. There is need for multidisciplinary engagement of expertise.
21.	Kazemian et al.	2022	Quantitative	Descriptive	Drivers of accounting for carbon management. Diversity is present.
22.	Kim et al.	2016	Quantitative	Experiment	There is an over- reliance on assurors in a senior position.
23.	Knechel	2021	Conceptual		Assurance reduces the risk in information
24.	Ioannou et al.	2016	Quantitative	OLS	The complexity of set targets is aligned with completion.
25.	Lodhia & Martin	2012	Qualitative	Concept and content analysis	There were diverging reactions to the energy act
26.	Luo et al.	2023	Quantitative	OLS	Assuring carbon emissions improves the quality of carbon emissions disclosures
27.	Mahmoudian et al.	2023	Quantitative	SEM and 3LS	When firms detail the assurance and projects, they are involved in to reduce carbon emission, cost of acquiring debt reduces.
28.	Mateo-Márquez et al.	2020	Quantitative	Tobit model regression	Regulation of climate change influences voluntary reporting of carbon emissions
29.	Martinov-Bennie	2012	Conceptual		Systems of governing and managing greenhouse gas emissions will increase with increased reporting

30.	Martinov-Bennie and Hoffman	2012	Qualitative	Semi-structured interviews	Accountants influence auditing in the greenhouse gas emission context
31.	Matsumura et al.	2014	Quantitative	Logit	The value of a firm reduces as more carbon emissions are emitted.
32.	Moroney et al.	2011	Quantitative	Content analysis	Carbon assurance improves the disclosure of environmental information
33.	Mia et al.	2019	Qualitative	Content analysis	Greenhouse gas data for cities needs improvement.
34.	Olson	2010	Qualitative	Content analysis	An integration of skills will be needed in the new greenhouse gas market since it is different from auditing of financial statements.
35.	Pitrakkos & Maroun	2020	Quantitative	Content analysis, Mann-Whitney U test	Disclosure of carbon emissions minimises legitimacy concerns.
36.	Ratnatunga	2007	Conceptual		Current frameworks of measuring, disclosing, and assuring carbon emissions are affecting the contribution of accountants in this new carbon context.
37.	Rohani et al.	2023	Quantitative	GMM	Taking on a higher assurance level does not guarantee a huge improvement in the performance of carbon emissions.
38.	Ryan & Tiller	2022	Quantitative	Descriptive	Few are reporting greenhouse gas emissions, assurance is even lower.
39.	Simic et al.	2023	Quantitative	Logit and probit regression	Availing higher payments for directors, increases chances of assuring carbon emissions
40.	Simnett	2007	Conceptual		Reviews Australia's accounting board and its consequences.
41.	Simnett and Nugent	2007	Conceptual		Discusses how to develop a standard for greenhouse gas emissions
42.	Simnett et al.	2010	Conceptual		Provision of assurance services in the new market will be conducted by two groups of assurors.
43.	Simnett et al.	2009	Conceptual		Discussed forms of carbon emission disclosures on which assurance may be sought.
44.	Tang & Luo	2014	Qualitative		Firms that manage their carbon emissions better can mitigate climate-change.
45.	Tang	2019	Quantitative	OLS	Creation of institutions that manage carbon emissions and government's investment in low carbon projects, drive the assurance of carbon.
46.	Tang & Demeritt	2018	Qualitative		Firms are financially incentivised to disclose their carbon emissions together with other pressures.
47.	Tauringana & Chithambo	2015	Quantitative	OLS	Regulatory guidelines and governance of corporate entities drives the disclosure of carbon emissions.
48.	Trotman & Trotman	2015	Qualitative	Interviews	Internal auditors play a role in the assurance of greenhouse gas emissions
49.	Vera-Munoz et al.	2020	Quantitative	Experiment	Including a tailored procedure does not affect the judgement of users.
50.	Xu & Andrew	2020	Qualitative		The Government was not the appropriate body to manage the conflicts between accounting and non-accounting assurors
51.	Zhou et al.	2022	Qualitative	Literature review	Drivers and outcomes of reporting climate- change and sustainability data
52.	Zhou et al.	2016	Quantitative	Logistic regression	Assurance of greenhouse gas emissions is driven by both country and firm factors

Appendix 11: Data extraction form: Other extracted information

No.	Author's name	Year of publication	Theoretical underpinnings	Reviewer's reflection	Gaps in research
1.	Ascui	2014	Literature review	Reviews carbon accounting literature but only two carbon assurance papers are reviewed.	How to measure climate-related finance Process of setting standards
2.	Bui et al.	2021	Stakeholder theory	If carbon assurance improves the quality of reports for firms listed on NYSE, do these results hold for firms listed on other exchanges or in developing and emerging contexts?	Future research should focus on different contexts e.g., firms that disclose outside the CDP, Institutional
3.	Busch et al.	2023	Descriptive study	Quality of data affects reporting and assurance of greenhouse gas emissions	How do standards for greenhouse gas emissions affect the accuracy of carbon emission data
4.	Chatterjee	2012	Stakeholder theory	Assurance is driven by business culture	Improve the definition of the users of greenhouse gas emissions. Examine greenhouse gas emission approaches
5.	Chithambo and Taurigana	2014	Agency theory Signaling theory Legitimacy theory Stakeholders' theory	Report quality does not improve despite regulation	Analyse content in other industrial contexts
6.	Comyns & Figge	2015	Legitimacy theory Stakeholders' theory	Greenhouse gas emission reporting is not improving. Why? Quality of reporting varies, what is causing the variations?	Quality of reporting greenhouse gas emissions should be improved.
7.	Comyns	2018	Institutional theory	Why do multinational corporations that operate across the globe register better greenhouse gas emissions reports than their peers?	How is regulation going to improve the quality of greenhouse gas reporting? More analysis of Multinational organisations' internal reporting practices is needed.
8.	Datt et al	2020	Legitimacy theory Stakeholders' theory	There are variations in the choice of assurors. Why do firms that operate in countries with stakeholder orientation prefer accountants, while those interested in modifying the management of carbon emissions prefer non- accountants.	Engage assurors through interviews to investigate the format of greenhouse gas reports, and how they navigate the challenges in assuring greenhouse gas emissions.
9.	Datt et al.	2019	Legitimacy theory	If high emitters in developed countries assure, is it also the same with those in developing and emerging countries? How about small firms, will they also be incentivised to assure even when they disclose outside the CDP?	Other drivers of carbon assurance should be examined. What drives decisions to assure with accounting versus specialist firms?
10.	Datt et al.	2018	Legitimacy theory Signaling theory Institutional theory	Adoption of carbon assurance is driven by several factors among which include a firm's risk exposure to carbon emissions. However, are there other factors that could influence adoption?	Is assuring carbon emissions valuable?
11.	Dutta P. & Dutta A.	2021	Stakeholder agency theory	Carbon assurance improves the disclosure of climate- related information in Finland. But can these results hold for developing and emerging countries, moreover for firms that disclose outside the CDP?	Does carbon assurance moderate disclosures of climate change and performance of carbon emissions
12.	Ekasingh et al.	2019	None-descriptive study	Does a diversity in expertise affect the effectiveness of assurance teams?	Be objective in measuring the effectiveness of teams
13.	Fan et al.	2021	Carbon information asymmetry theory	Can carbon assurance lower information gaps for firms that disclose outside the CDP?	Effect of assuring carbon emissions on management of carbon, performance related to reducing carbon emissions
14.	Green & Li	2012	None-descriptive study	How can we bridge gaps in stakeholders' expectations?	Can the gaps in stakeholders' expectations be reduced using standards?

15.	Green & Taylor	2013	None-descriptive study	What other factors may influence the assuror quality?	Comparisons and contrasts should be made when greenhouse gas assurance market is more mature.
16.	Green & Zhou	2013	None-descriptive study	Dichotomous, diverse market	What drives decisions to assure with accounting versus specialist firms? Assurance quality needs to be investigated.
17.	Green et al.	2009	None-descriptive study	What specific skills should accountants and non-accountants have in assurance of greenhouse gas emissions? What are the differences in these skills? How can we integrate these skills to improve quality of assurance engagement?	Compare conclusions made by accountants on the assurance of greenhouse gas emissions to those of specialist, and in multidisciplinary teams
18.	Hay et al.	2023	Descriptive study		How should harmonisation of the assurance standard be conducted
19.	He et al.	2022	Literature review	Carbon accounting is distinct from traditional accounting.	Improve theorisation in the field, interactions among the 4 streams
20.	Huggins et al.	2011	Descriptive study	What roles do assurors play in this new market, and do the roles played by accountants differ from specialist roles?	What drives the choice of assurance standard?
21.	Kazemian et al.	2022	Descriptive study	How do these practices differ for developing and emerging countries?	Undertake a longitudinal study to investigate carbon management practices
22.	Kim et al.	2016	Source credibility theory	Over reliance on senior experts creates bias in assurance engagements	Investigate the process of integrating accounting and technical expertise
23.	Knechel	2021	Descriptive study		There is need to expand assurance, regulation has a big role to play.
24.	Ioannou et al.	2016	None-descriptive study	Can low targets yield high performance? under what circumstances may low targets improve performance?	How does the setting of targets and allocated incentive affect performance?
25.	Lodhia & Martin	2012	Agenda-setting perspective	How do stakeholders' beliefs shape policy formulation in greenhouse gas emissions reporting and assurance?	A shift in investigative methods like interviews could also yield interesting findings
26.	Luo et al.	2023	Credibility enhancement Signaling, Governance	The effect of carbon assurance on the quality of carbon emission reporting varies depending on several factors.	Effect of assuring carbon emissions on management of carbon
27.	Mahmoudian et al.	2023	Theory of voluntary disclosure	Do firms in developing and emerging countries also report reductions in the debt cost?	Need to change contexts in future studies, for instance firms that report outside that CDP and operate in developing/ emerging economies.
28.	Mateo-Márquez et al.	2020	Institutional theory	Can the absence of regulation affect the disclosure of carbon emissions?	How to the regulations in other countries influence the reporting of carbon disclosures
29.	Martinov-Bennie	2012	Descriptive study	How do governance and management mechanisms of carbon emissions influence disclosure and audit?	How can costs of assuring greenhouse gas emissions be minimized while maximising the benefits therein?
30.	Martinov-Bennie and Hoffman	2012	None-descriptive study	How can the perspectives of non- accountants be integrated in the energy regulations?	Use other sources of data, monitor the changing trends in the assurance market
31.	Matsumura et al.	2014	None-descriptive study	If emissions affect the value of the firm, how specifically do they affect debt and equity cost? Are there differences in impact?	Investigate influence of carbon emissions on either cost of debt or cost of equity.
32.	Moroney et al.	2012	Stakeholder agency theory	Does carbon assurance have the same effects for firms that are not listed?	Does carbon assurance influence small firms' disclosure of environmental information?
33.	Mia et al.	2019	None-descriptive study	How can we improve the quality of greenhouse gas information at city level?	Conduct a longitudinal study to investigate whether carbon emissions have reduced in cities.
34.	Olson	2010	Descriptive study	How can the knowledge from auditing financial statements be shifted to the new practice?	Investigate how to overcome the stated challenges and hance the opportunities that lie in carbon assurance.

35.	Pitrakkos & Maroun	2020	Legitimacy theory	What affects the disclosure quality?	What drives stakeholders to make firms be responsive for their emissions?
36.	Ratnatunga	2007	Descriptive study	The market should be regulated	How can carbon emissions be managed?
37.	Rohani et al.	2023	Legitimacy view, Outside-in-management view	Do firms want to improve performance or want to look legitimate?	What are managers' perceptions regarding the varying assurance levels?
38.	Ryan & Tiller	2022	Review	Are there similarities in assurance practices of developed countries compared with developing countries?	Would mandating greenhouse gas emissions reporting increase reporting?
39.	Simic et al.	2023	Stakeholders' theory	If compensation drive the adoption of carbon assurance in UK, then what will drive the adoption in the absence of such incentives. Do firms also assure in the absence of such incentives?	Investigate study in developing or emerging contexts.
40.	Simnett	2007	Descriptive study	Are the differences in assurance practices of large versus small firms?	How are greenhouse gas assurance standards implemented for SMEs?
41.	Simnett and Nugent	2007	Descriptive study	Competences in greenhouse gas emissions assurance go hand in hand with regulations.	Investigate the drivers of greenhouse gas assurance
42.	Simnett et al.	2010	Descriptive study	How can we improve enforcement of assurance standards? What is hindering their enforcement?	Who should use what assurance standard?
43.	Simnett et al.	2009	Descriptive study	Is the new standard for assurance of greenhouse gas emissions the solution to the challenges in the new market?	More clarity is required for greenhouse gas emissions standard.
44.	Tang and Luo	2014	Conceptual study	Will firms without carbon management systems also register decline in carbon emissions? If not, then what is hindering the reduction, is it attributed to the lack of a carbon management system or other factors?	Does controlling carbon emissions affect firm value?
45.	Tang	2019	Transition management theory	What other factors drive the adoption of carbon assurance in China besides those examined?	How is the carbon assurance implemented?
46.	Tang and Demeritt	2018	Descriptive study	Will firms disclose carbon emissions in the absence of incentives and external pressures?	Use different contexts when investigating reporting of carbon emissions
47.	Tauringana and Chithambo	2015	Stakeholder -agency theory	With or without a disclosure mandate, firm disclose emissions. What drives this disclosure?	Conduct the same study in different contexts
48.	Trotman and Trotman	2015	Agency theory Institutional theory Resource dependence theory	Can internal auditors perform an equally good job in this new assurance engagement compared to external assurance? Are there similarities or differences in performance by these two methods?	Need to investigate more interactions between the internal auditor and other stakeholders.
49.	Vera-Munoz et al.	2020	Communication theory	Do practitioner procedures influence users' decisions?	Does the market react differently to reports assured using different standards?
50.	Xu and Andrew	2020	Trials of strength and responsibility	Can accountants work harmoniously alongside specialists, if Government failed to harmonise their roles, then who is best suited for this task?	Carry out a study to compare how accounting and specialist consultants assure a given level of assurance.
51.	Zhou et al.	2022	Literature review	Drivers and outcomes of these climate- related information are examined? How about the process?	Investigate misconduct Environmental, social Governance reporting
52.	Zhou et al.	2016	Stakeholder's theory	What other factors can drive adoption of carbon assurance? If the contexts are changed, will the results still hold?	Are there any differences in quality between assurance provided by accountants and that provided by non- accountants?

Appendix 12: Definitions and categories of research papers

Type of paper	Explanation
Conceptual	Explains the main points to be studied; namely, the key factors, concepts, variables, and presumes relationships among them (Miles & Huberman, 1994)
Theoretical	Offers new theoretical position or questions the fundamental structure of an existing theory (Whetten, 1989)
Qualitative	Do not use the data indicating the ordinal values and generally focus on non-numeric data, including texts, images, and behavioural patterns (Nkwi, Nyamongo & Ryan, 2001)
Quantitative	Explains a phenomenon by using numerical data and analyses the same with mathematical methods (Aliaga & Gunderson, 2002)

Appendix 13: Evaluation of Journals publishing carbon assurance studies

No.	Author's name	Year of publication	Type of journal	Journal Ranking	Discipline
1	Simnett	2007	Australian Accounting Review	2B	Accounting
2	Simnett and Nugent	2007	Current issues in Auditing	2B	Accounting
3	Ratnatunga	2007	Journal of Applied Management Accounting research	unknown	unknown
4	Simnett et al.	2009	Accounting horizons	3A	Accounting
5	Green et al.	2009	Environment	unknown	Unknown
6	Simnett et al.	2010	Current Issues in Auditing	2B	Accounting
7	Olson	2010	Managerial Auditing Journal	2A	Accounting
8	Moroney et al.	2011	Accounting and Finance	2A	Accounting
9	Huggins et al.	2011	Current issues in Auditing	2B	Accounting
10	Green & Li	2012	Accounting, Auditing & Accountability Journal	3A*	Accounting
11	Lodhia & Martin	2012	Accounting, Auditing, and Accountability Journal	3A*	Accounting
12	Martinov-Bennie and Hoffman	2012	Australian Accounting Review	2B	Accounting
13	Chatterjee	2012	Journal of Asia Pacific Centre for	unknown	unknown

14	Martinov-Bennie	2012	Environmental Accountability Sustainability Accounting, Management and Policy Journal	2B	Accounting
15	Green & Zhou	2013	Australian Accounting Review	2B	Accounting
16	Green & Taylor	2013	International Journal of Auditing	2A	Accounting
17	Tang	2014	Australian Accounting Review	2B	Accounting
18	Chithambo and Taurigana	2014	Journal of Applied Accounting Research	2B	Accounting
19	Ascui	2014	Social and Environmental Accountability Journal	1B	Accounting
20	Matsumura et al	2014	The Accounting review	4*A*	Accounting
21	Comyns & Figge	2015	Accounting, Auditing & Accountability Journal	3A*	Accounting
22	Trotman and Trotman	2015	Auditing: A journal of practice and Theory	3A*	Accounting
23	Tauringana and Chithambo	2015	The British Accounting Review	3A*	Accounting
24	Zhou et al.	2016	Auditing: A Journal of Practice & Theory	3A*	Accounting
25	Kim et al.	2016	Auditing: A journal of practice and Theory	3A*	Accounting

26	Loannou et al.	2016	The Accounting review	4*A*	Accounting
27	Comyns	2018	Accounting Forum	3B	Accounting
28	Tang and Demeritt	2018	Business strategy and the Environment	3A	Environment
29	Datt, Luo, Tang and Mallik	2018	Journal of International Accouinting Research	2A	Accounting
30	Datt et al	2019	Accounting Research Journal	2B	Accounting
31	Tang	2019	Australian Accounting Review	2B	Accounting
32	Ekasingh, Simnett, and Green	2019	Behavioral Research in Accounting	3A	Accounting
33	Mia et al	2019	Sustainability Accounting, Management and Policy Journal	2B	Accounting
34	Vera-Munoz et al.	2020	Auditing: A journal of practice and Theory	3A*	Accounting
35	Xu and Andrew	2020	Critical perspectives on accounting	3A	Accounting
36	Datt et al	2020	International Journal of Auditing	2A	Accounting
37	Marquez et al.	2020	Sustainability Accounting, Management and Policy Journal	2B	Accounting
38	Pitrakkos & Maroun	2020	Sustainability Accounting,	2B	Accounting

			Management and Policy Journal		
39	Knechel	2021	Accounting horizons	3A	Accounting
40	Bui et al.	2021	Business strategy and the Environment	3A	Environment
41	Dutta P & Dutta A	2021	Journal of Applied Accounting Research	2B	Accounting
42	Fan et al	2021	The British Accounting Review	3A*	Accounting
43	He et al	2022	Accounting and Finance	2A	Accounting
44	Ryan & Tiller	2022	Australian Accounting Review	2B	Accounting
45	Zhou et al.	2022	Australian Accounting Review	2B	Accounting
46	Kazemian et al	2022	Sustainability Accounting, Management and Policy Journal	2B	Accounting
47	Hay et al	2023	Accounting and Finance	2A	Accounting
48	Luo et al.	2023	Accounting and Finance	2A	Accounting
49	Simic et al	2023	International Journal of Auditing	2A	Accounting
50	Rohani et al	2023	Journal of Applied Accounting Research	2B	Accounting
51	Mahmoudian et al	2023	Journal of International Accounting, Auditing and Taxation	3B	Accounting

52	Busch et al	2023	Journal of Business ethics	3A	Ethics

Appendix 14: Coding structure**:** codes, categories, and associated themes

Theme	Categories	Codes
1. Definition of carbon assurance		Carbon auditing Climate change (2) Evaluation GHG emissions Organizational factors: organisation
2. Carbon assurance approaches		
2.1 Greenhouse gas statement assurance	Purpose	Assurance: Independent auditing Verification
	Scope	Carbon auditing Carbon mitigation
2.2 Compliance carbon audit	Nature	Carbon regulation
	Users	Climate change and carbon management: Climate change audit
2.3 Carbon management audit	Antecedents	Climate change and carbon management: Climate legislation
	Process	Compliance (2)
	Outcome	Climate change and carbon management: Climate legislation
	Challenges	Climate change and carbon management: CO2-equivalent emissions Climate change and carbon management: Carbon management system CMA practice Skepticism
2.4 Governmental climate change audit		Climate change policy Environmental regulations (2): Ecological efficiency Government and policy: Public climate policy
3. Emerging themes		
3.1 Emerging themes on antecedents	External Antecedents	Corporate environment: External factors
	▪ Climate change	Climate change (2) Carbon emissions Climate change: climate change Climate change: extreme weather Global warming Legitimacy Motivation Temperature increase Forest fires Ice melting
	▪ Regulation	Carbon market Carbon pricing Carbon: carbon legislation Corporate environment: Regulatory pressures Environmental regulations Institutional context Legal and Regulatory: International markets Legal and Regulatory: International trade Regulations Accounting and business: Economic openness
	▪ Stakeholder orientation	Administrative: Institutional arrangement Corporate finance: Business culture Corporate sustainability: Stakeholder engagement Stakeholder orientation
	▪ Industry	Carbon- intensive sector

	▪ Government investment in low carbon projects	Climate change (2) Climate change and carbon management: Green investment Climate change and carbon management: Low carbon economy Environment Investment Government and Policy: Government policies
Internal Antecedents		Carbon accounting: Demand for carbon assurance Corporate environment: Internal factors Assurance: Demand for Independent verification
	▪ Carbon risk exposure	Carbon: Carbon risk exposure Carbon accounting: Carbon risk
	▪ Carbon emission disclosures	Disclosure: Selective disclosure Disclosures Environmental reporting (2): carbon emissions reduction
	▪ Carbon governance mechanisms	Environmental reporting (2): Greenwash.
	❖ Environmental committee	Carbon governance Governance Assurance: Assurance Carbon mitigation Climate change policy Disclosure (2)
	❖ Compensation and carbon reduction incentives	Stakeholder engagement Sustainability Assurance: Third party verification Carbon reduction Compensation: Director compensation Compensation: Influence of compensation Governance Incentives Managerial incentives
	❖ Carbon transparency	Carbon: Carbon transparency Corporate social responsibility
	❖ Proactivity and carbon reduction activity	Decision making Accounting and Business: Proactivity
	▪ Carbon information asymmetry	Carbon: Carbon reduction activity Carbon: Voluntary third-party carbon assurance Carbon accounting: Carbon legislation Carbon accounting: Carbon intensive sectors Carbon accounting: Carbon information asymmetry Carbon accounting: Energy sources Carbon accounting: Fuel consumption Carbon emissions Climate change: Environmental management
	▪ Corporate governance	Corporate governance (2): Business landscape Corporate governance (2): Firm sustainability Corporate governance (2): Non-financial information Corporate governance (2): Shareholder returns
	▪ Carbon performance	Carbon assurance Carbon: Carbon performance Corporate disclosure (2): Management performance Corporate disclosure (2): Managerial control Information quality: Quality of information
	▪ Firm size	Business: Size of company Business metrics: Visibility Corporate disclosures (2): stakeholder scrutiny Corporate disclosure (2): Public scrutiny Firm: Firm size Legitimacy (2): legitimacy threat Legitimacy (2): media coverage
	▪ Leverage	

3.2 Emerging themes on Outcomes	Reporting integrity	Carbon emissions (2): Quality carbon disclosure
		Assurance: Reporting mechanism
		Carbon reporting
	Carbon disclosure	Climate-change disclosure
	Climate change disclosure	Corporate disclosure: management tool
	Environmental disclosure	Environmental disclosures
	Credibility of carbon disclosure	Environmental reporting
	Firm value	Environmental sustainability
		Firm value
		Financial management: cost of debt
		Administrative: Credibility enhancement
		Credibility
		Economic factors (2): Cost reduction
3.3 Emerging themes on Challenges	Voluntary nature of carbon assurance	Assurance: Independent assurance
		Assurance: Self reporting
		Business Operations
		Carbon assurance
		Carbon auditing
		Carbon: Carbon assurance largely voluntary
		Credibility
		Codes: Incompatibility
		Environmental Impact
		Lack of consistency
	Governance challenges	Assurance: Reporting boundaries
		Multidisciplinary: multi-disciplinary teams
		Opportunities: Market duality
	Associated challenges	
	Measurement challenges	Accuracy
		Complexity (2): Variability
		Data analysis: Continuous measurement
		Data analysis: Measurement challenges
		Data analysis: Cost effectiveness
		Inconsistency (2): Inadequate training
		Inconsistency (2): Lack of accuracy
		Inconsistency (2): Obstacle
	Environmental stewardship	Business: Manufacturing
		Business: Shared ownership
		Business: Packaging
		Business: Product use
		Climate change: Environmental stewardship
		Environmental sustainability (2): Environmental stewardship
	Aggregation of Global greenhouse gas emissions	Accuracy
		Business: Business
		Climate change (2)
		Corporate governance (2): Copenhagen Accord
	Non-standard boundary conditions	Business: Planning
		Cooperation
		Professional ethics: standards
		Reporting (2)
	Costs	Cost: cost consideration
	Alternatives to external assurance	Assurance: Internal audit
		Internal audit
3.4 Growth opportunities of carbon assurance	Differentiation and competitive advantage	Business: Brand image
		Business: Competitive advantage
		Environmental sustainability
		Stock market
	Recognition and awards	Business: Publicity
		Miscellaneous: Recognition
		Miscellaneous: Awards
		Sustainability
	Reduced impact of global warming	Business: Global industrialization

		Business: Revenue Growth Business: Population growth Environmental sustainability (2): Environmental stewardship Efficiency Opportunity
4. Theoretical underpinnings	Stakeholders	Stakeholder theory
	Stakeholders-agency	Accountability (2) Business metrics: Neighborliness Business metrics: Survival Business metrics: Relationship Corporate Governance (2): Stakeholder- agency theory Corporate Governance: Agency theory Disclosure: Environmental disclosure Economic factor (2): Long term survival Institutionalisation: Agency theory Legal and regulatory: Regulation Stakeholders Employees Expectations
	Legitimacy	Climate change Climate change: Environmental sustainability Corporate disclosure: Human capital Corporate sustainability: Public image Corporate Governance: Investor decision making. Economic factors: long -term survival Institutionalisation: Legitimacy Legitimacy Legitimacy theory
	Institutional	Business metrics: Culture Business metrics: Norm Compliance: Standards and regulation Compliance: Regulation Environmental conservation: Environmental agencies Environmental: success External Legitimacy Institutional theory Institutionalisation: Institutional context Institutionalisation: Institutional theory
	Signaling	Administrative: Signaling Corporate disclosure: Local communities Environmental responsibility Miscellaneous: Signaling
	Credibility enhancement	Administrative: Credibility enhancement Corporate responsibility (2): Stakeholder relationship Trust Governance
	Outside-in-management view	Climate-related disclosure: carbon performance Improvement (2): Performance improvement
	Carbon information asymmetry	Carbon accounting: Carbon information asymmetry Carbon accounting: Corporate carbon information gap Disclosure: Environmental information asymmetry
	Transition management	Business: Financial Investment Cost of capital Finance Standards: Transition management Transition management

Appendix 15: Code and category definitions

Theme	Category definition	Categories	Code definition	Codes
1. Definition of carbon assurance	Statements that define carbon assurance		Statements that define carbon assurance	Carbon auditing Climate change (2) Evaluation GHG emissions Organisational factors: organisation
2. Carbon assurance approaches				
2.1 Greenhouse gas statement assurance	Statements that describe the approaches of carbon assurance.	Purpose	Statements that describe the characteristic approaches of carbon assurance in terms of purpose, scope, nature, users, antecedents, process, outcomes, challenges	Assurance: Independent auditing Verification
		Scope		Carbon auditing Carbon mitigation Carbon regulation
2.2 Compliance carbon audit		Nature		
		Users		Climate change and carbon management: Climate change audit
2.3 Carbon management audit		Antecedents		Climate change and carbon management: Climate legislation Compliance (2)
		Process Outcome		Climate change and carbon management: Climate legislation
		Challenges		Climate change and carbon management: CO2-equivalent emissions Climate change and carbon management: Carbon management system CMA practice Skepticism
2.4 Governmental climate change audit				Climate change policy Environmental regulations (2): Ecological efficiency Government and policy: Public

				climate policy
3. Emerging themes				
3.1 Emerging themes on antecedents	Statements that describe the external factors that drive the adoption of carbon assurance.	External Antecedents ▪ Climate change ▪ Regulation ▪ Stakeholder orientation ▪ Industry ▪ Government investment in low carbon projects	Statements that describe business culture, climate-change, regulatory, industry factors that drive the adoption of carbon assurance.	Corporate environment: External factors Climate change (2) Carbon emissions Climate change: climate change Climate change: extreme weather Global warming Legitimacy Motivation Temperature increase Forest fires Ice melting Carbon market Carbon pricing Carbon: carbon legislation Corporate environment: Regulatory pressures Environmental regulations Institutional context Legal and Regulatory: International markets Legal and Regulatory: International trade Regulations Accounting and business: Economic openness Administrative: Institutional arrangement Corporate finance: Business culture Corporate sustainability: Stakeholder engagement Stakeholder orientation Carbon- intensive sector Climate change (2) Climate change and carbon management: Green investment Climate change and carbon management: Low carbon economy

Statements that describe the internal factors that drive the adoption of carbon assurance.	Internal Antecedents ▪ Carbon risk exposure ▪ Carbon emission disclosures ▪ Carbon governance mechanisms ❖ Environmental committee ❖ Compensation and carbon reduction incentives ❖ Carbon transparency ❖ Proactivity and carbon reduction activity ▪ Carbon information asymmetry	Statements that describe carbon risk exposure, carbon emission disclosures, carbon information asymmetry, carbon performance, firm size, leverage, corporate governance, carbon governance factors that drive the adoption of carbon assurance.	Environment Investment Government and Policy: Government policies Carbon accounting: Demand for carbon assurance Corporate environment: Internal factors Assurance: Demand for Independent verification Carbon: Carbon risk exposure Carbon accounting: Carbon risk Disclosure: Selective disclosure Disclosures Environmental reporting (2): carbon emissions reduction Environmental reporting (2): Greenwash. Carbon governance Governance Assurance: Assurance Carbon mitigation Climate change policy Disclosure (2) Stakeholder engagement Sustainability Assurance: Third party verification Carbon reduction Compensation: Director compensation Compensation: Influence of compensation Governance Incentives Managerial incentives Carbon: Carbon transparency Corporate social responsibility Decision making Accounting and Business: Proactivity Carbon: Carbon reduction activity Carbon: Voluntary third-party carbon assurance Carbon accounting: Carbon legislation Carbon accounting: Carbon

				intensive sectors Carbon accounting: Carbon information asymmetry Carbon accounting: Energy sources Carbon accounting: Fuel consumption Carbon emissions Climate change: Environmental management Corporate governance (2): Business landscape Corporate governance (2): Firm sustainability Corporate governance (2): Non-financial information Corporate governance (2): Shareholder returns Carbon assurance Carbon: Carbon performance Corporate disclosure (2): Management performance Corporate disclosure (2): Managerial control Information quality: Quality of information Business: Size of company Business metrics: Visibility Corporate disclosures (2): stakeholder scrutiny Corporate disclosure (2): Public scrutiny Firm: Firm size Legitimacy (2): legitimacy threat Legitimacy (2): media coverage
		▪ Corporate governance ▪ Carbon performance ▪ Firm size ▪ Leverage		
3.2 Emerging themes on Outcomes	Statements that describe the consequences of carbon assurance.	Reporting integrity	Statements that describe how carbon assurance affects reporting quality, carbon disclosures, climate change disclosures, environmental disclosures	Carbon emissions (2): Quality carbon disclosure Assurance: Reporting mechanism Carbon reporting
		Carbon disclosure Climate change disclosure Environmental disclosure Credibility of carbon disclosure		Climate-change disclosure Corporate disclosure: management tool Environmental disclosures

		Firm value		Environmental reporting Environmental sustainability Firm value Financial management: cost of debt Administrative: Credibility enhancement Credibility Economic factors (2): Cost reduction
3.3 Emerging themes on Challenges	Statements that describe the challenges that affect carbon assurance.	Voluntary nature of carbon assurance	Statements that describe the voluntary nature of assurance, governance, associated, measurement, environmental stewardship, aggregation of global greenhouse gas emissions, non- standard boundary conditions, carbon assurance costs, alternatives to external assurance challenges that affect carbon assurance	Assurance: Independent assurance Assurance: Self reporting Business Operations Carbon assurance Carbon auditing Carbon: Carbon assurance largely voluntary Credibility Codes: Incompatibility Environmental Impact Lack of consistency
		Governance challenges		Assurance: Reporting boundaries Multidisciplinary: multi-disciplinary teams Opportunities: Market duality
		Associated challenges		
		Measurement challenges		Accuracy Complexity (2): Variability Data analysis: Continuous measurement Data analysis: Measurement challenges Data analysis: Cost effectiveness Inconsistency (2): Inadequate training Inconsistency (2): Lack of accuracy Inconsistency (2): Obstacle
		Environmental stewardship		Business: Manufacturing Business: Shared ownership Business: Packaging Business: Product use Climate change: Environmental

				stewardship
		Aggregation of Global greenhouse gas emissions		Environmental sustainability (2): Environmental stewardship Accuracy Business: Business Climate change (2)
		Non-standard boundary conditions		Corporate governance (2): Copenhagen Accord Business: Planning Cooperation Professional ethics: standards Reporting (2)
		Costs		Cost: cost consideration
		Alternatives to external assurance		Assurance: Internal audit Internal audit
3.4 Growth opportunities of carbon assurance	Statements that describe the growth opportunities available in carbon assurance	Differentiation and competitive advantage	Statements that describe differentiation and competitive advantage, recognition and awards, reduced impact of global warming opportunities of carbon assurance	Business: Brand image Business: Competitive advantage Environmental sustainability Stock market Business: Publicity
		Recognition and awards		Miscellaneous: Recognition Miscellaneous: Awards Sustainability
		Reduced impact of global warming		Business: Global industrialization Business: Revenue Growth Business: Population growth Environmental sustainability (2): Environmental stewardship Efficiency Opportunity

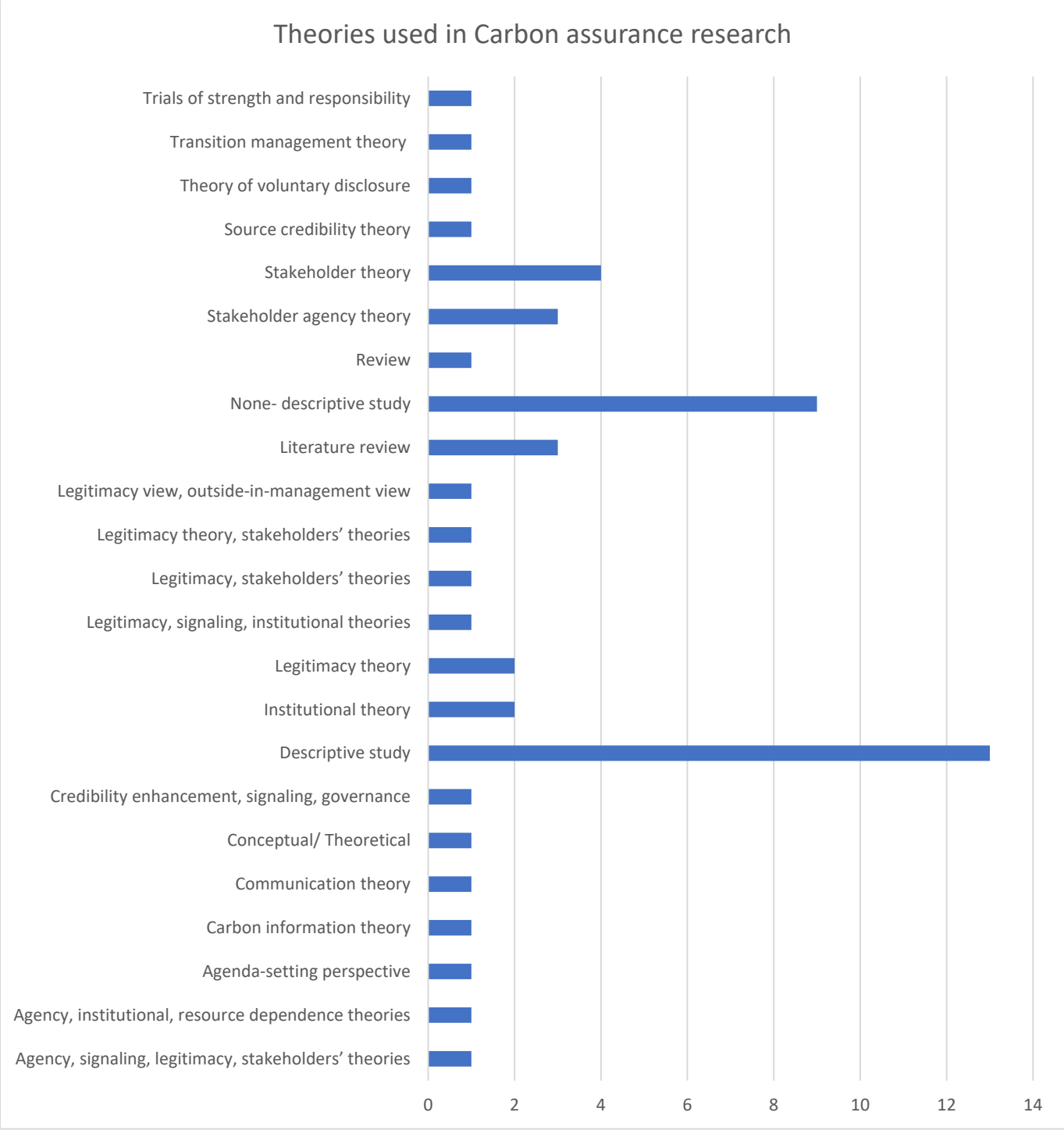
4. Theoretical underpinnings	Statements that describe the theorisation of carbon assurance	Stakeholders Stakeholders-agency	Statements that describe stakeholder, stakeholder- agency, legitimacy, institutional, signaling, credibility enhancement, outside-in-management view, carbon information asymmetry, transition management theoretical lenses used in carbon assurance	Stakeholder theory Accountability (2) Business metrics: Neighborliness Business metrics: Survival Business metrics: Relationship Corporate Governance (2): Stakeholder- agency theory Corporate Governance: Agency theory Disclosure: Environmental disclosure Economic factor (2): Long term survival Institutionalisation: Agency theory Legal and regulatory: Regulation Stakeholders Employees Expectations
		Legitimacy		Climate change Climate change: Environmental sustainability Corporate disclosure: Human capital Corporate sustainability: Public image Corporate Governance: Investor decision making. Economic factors: long -term survival Institutionalisation: Legitimacy Legitimacy Legitimacy theory
		Institutional		Business metrics: Culture Business metrics: Norm Compliance: Standards and regulation Compliance: Regulation Environmental conservation: Environmental agencies Environmental: success External Legitimacy Institutional theory Institutionalisation: Institutional

	context Institutionalisation: Institutional theory
Signaling	Administrative: Signaling Corporate disclosure: Local communities Environmental responsibility Miscellaneous: Signaling
Credibility enhancement	Administrative: Credibility enhancement Corporate responsibility (2): Stakeholder relationship
Outside-in-management view	Trust Governance Climate-related disclosure: carbon performance Improvement (2): Performance improvement
Carbon information asymmetry	Carbon accounting: Carbon information asymmetry Carbon accounting: Corporate carbon information gap Disclosure: Environmental information asymmetry
Transition management	Business: Financial Investment Cost of capital Finance Standards: Transition management Transition management

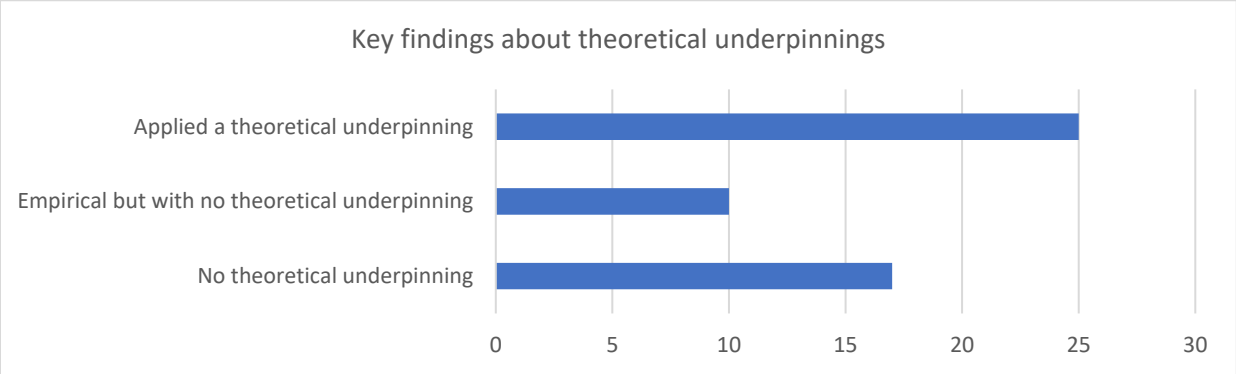
Appendix 16: Carbon assurance antecedents

External drivers	Internal drivers
Climate-change pressures Carbon regulation pressures Industry pressures	Carbon risk exposure Carbon emission disclosure Carbon governance ❖ Environmental committee ❖ Compensation and carbon reduction incentives ❖ Carbon transparency ❖ Proactivity and carbon reduction activity
Stakeholder orientation Government investment in low carbon projects	Carbon information asymmetry Corporate governance Carbon performance Firm size Leverage

Appendix 17: Theoretical underpinnings in carbon assurance



Appendix 18: Key findings from the Theoretical underpinnings



Appendix 19: Concept analysis using Atlas. ti qualitative data analysis

The analysis of data using ATLAS.TI, began with concept analysis that was performed to identify the number of concepts in the data as well as their frequency. The concepts that appeared most in the data were assurance with 4945 outcomes followed by carbon with 4916 outcomes, and emissions with 4070 outcomes, as shown in the concept cloud in **Figure 1.**

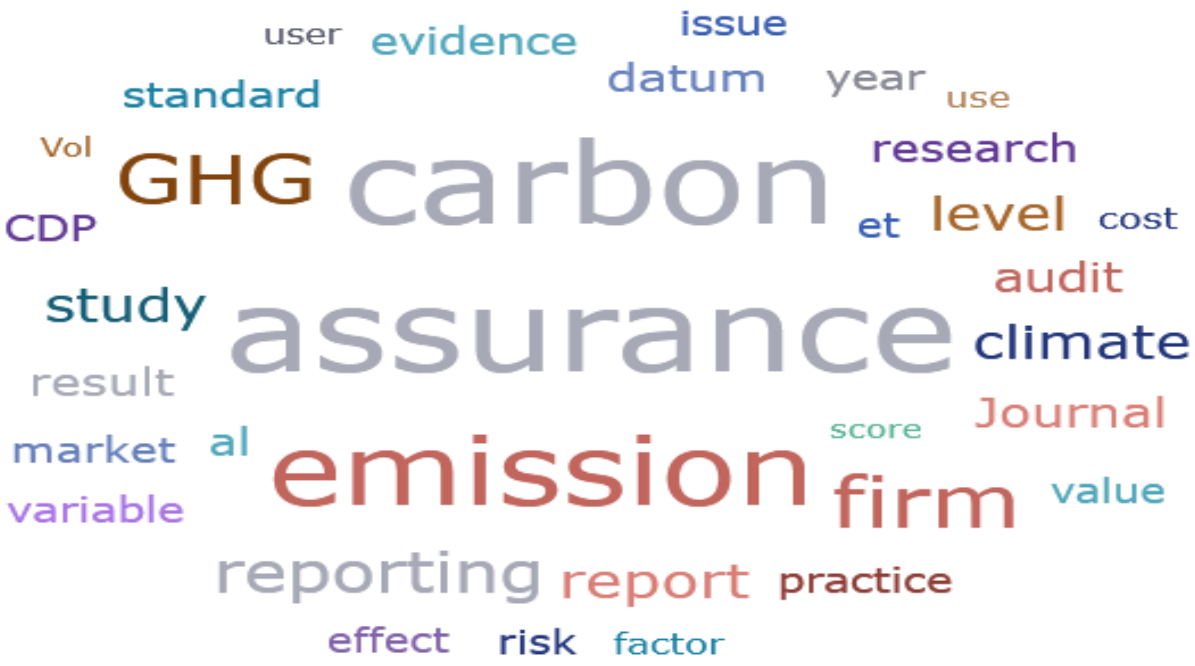


Figure 1: Concept cloud

Appendix 20: Word analysis using Atlas. ti qualitative data analysis

The reviewer then carried out a word frequency analysis to identify which words were appearing most in the data and to compare the results with those of the concept analysis. In contrast, the word carbon appeared most from the data with 5910 tokens, followed by assurance with 5837 tokens. There was a slight increase in the frequency of emissions by 95 tokens, though it still held the third position. The words reporting, firm, GHG, audit, were common to both the concept cloud and word cloud while the words governance, team, standard, level, role, user, had a less representation in the data as shown in the concept cloud in **Figure 2.**

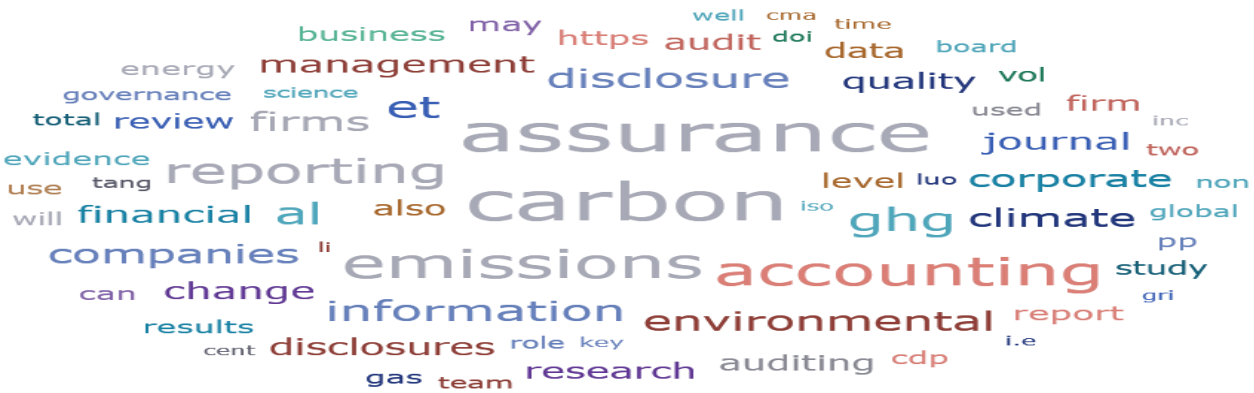


Figure 2: Word cloud

Appendix 21: Code group analysis using Atlas. ti qualitative data analysis

The reviewer grouped the codes into categories to identify the commonly appearing categories in the data. Results indicated that, climate change, appeared most from the data with 470, followed by corporate governance with 302, carbon emissions with 288, standards with 260, disclosure with 202, and transparency with 101. While the least common categories were leverage with 26, trust with 21, costs with 13 as shown in the concept cloud in **Figure 3.**

Appendix 22: Coding using Atlas. ti qualitative data analysis

Institutional Influence, Transition Management and the Demand for Carbon Auditing: The Chinese Experience

Qingliang Tang, Western Sydney University

The primary objective of this study is to investigate factors associated with the increase in demand for carbon auditing in China. Based on an analysis of publicly available carbon-related information and data, the paper documents the large amount of carbon auditing that occurred in the public sector during the period 2009–2015. We find that the creation of carbon institutions and the significant increase in governmental green funding were the main reasons for the emergence of carbon auditing in this period. The change in models of economic development attempting to balance GDP growth and ecosystem protection, in addition to institutional reforms, has led carbon auditing from rhetoric to practice. In addition, we show that carbon auditing serves as a tool for the management of transitions and the governance of sustainable socio-technical and organisational innovation and transformation.

Currently there exists a rapidly escalating environmental crisis in China, featuring increasingly severe air and water pollution and an ever deteriorating ecosystem. The current model of economic development may be responsible for the problem through its overwhelming emphasis on the accumulation of financial wealth combined with a disregard for any negative impact on ecological systems. There have been urgent calls for change in the economic model. One of the main issues cited is the control of carbon emissions (Climate Change and Low Carbon Economy Research Institute of Chinese People's University 2012). The Chinese Government has committed itself to a reduction of greenhouse gas (GHG) emissions by 17% per unit of GDP by the end of 2015.[1]

Achievement of this goal will require the efforts of the entire community. Auditors are expected to play a role as well. Although there is limited literature on carbon auditing, its importance has been recognised in the literature (Green and Taylor 2013; Trotman and Trotman 2015) due to institutional changes such as emissions trading schemes (ETSs) that have emerged as a favoured mechanism for the reduction of carbon emissions. In such a system, carbon emissions are given a price that internalises the external cost of emissions so as to allow carbon control to enter the process of corporate decision making (Luo and Tang 2014a). This creates a legitimacy pressure for firms to disclose their carbon information, and carbon accounting and assurance is becoming more and more a desirable aspect of good accountability among corporate operations. Therefore, the Big 4 accounting firms are currently among the market leaders providing sustainability assurance services (Vendantis 2011). The scope of these assurance services includes carbon emissions inventory, measurement of the carbon footprint, carbon activity, carbon-reduction performance, and whether carbon activity conforms with climate change legislation. The importance of quality driven carbon assurance is highlighted by the new international GHG assurance standard, ISAE 3410 *Assurance on a Greenhouse Gas Statement* (effective from 2013), issued by the International Auditing and Assurance Standards Board (IAASB). While there are a growing number of jurisdictions where carbon disclosure is compulsory, carbon assurance is largely voluntary (Green et al. 2009; Green and Li 2012) and many companies around the world voluntarily assure their emissions information (Green and Zhou 2013). Nevertheless there is limited research on carbon auditing in the extant literature (Datt et al. 2010).

This paper documents a series of special audits (carbon audits) undertaken by the China National Audit Office (CNAO) between 2009 and 2013. The auditors examined governmental agencies, state-owned enterprises (SOEs) and other organisations that used funds provided by the Government for 'green' initiatives (i.e., projects intended to reduce GHG emissions and improve energy efficiency). The auditing investigated whether these funds had been used in accordance with laws and regulations and whether they had achieved their objectives.

The purposes of the study are twofold. First, we attempt to investigate why the demand for carbon auditing

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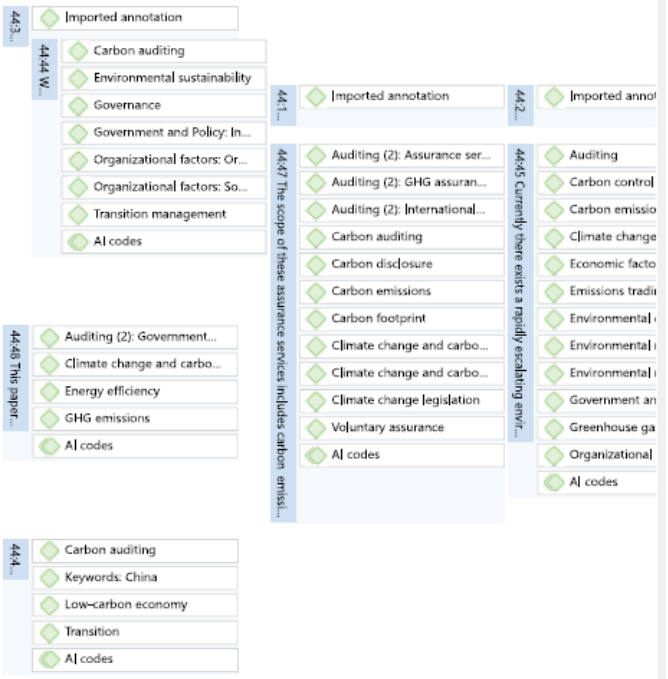

Appendix 23: Current and future research in carbon assurance

Item		What we know	What has not yet been studied
1.	**Carbon assurance definition**		Definition of carbon assurance
2..	**Carbon assurance approaches**	Purpose, Scope of assurance Nature of assurance Users of reports	Antecedents, process, outcomes, challenges, user expectations and perceptions in terms of report quality, uses of the reports, and user preferences for assurance provider
3.	**Emerging themes in carbon assurance**		
	3.1 Emerging themes on antecedents	**Internal antecedents:** Carbon risk exposure Carbon emission disclosure Carbon information asymmetry Carbon performance Firm size Leverage Corporate governance ▪ Gender diverse ▪ Duality ▪ CSR committees Carbon governance ▪ Environment committee ▪ Compensation and carbon reduction incentives ▪ Carbon transparency ▪ Proactivity and carbon reduction	▪ Size of the board ▪ Board tenure ▪ Female executive directors ▪ CEO global working experience ▪ Board independence ▪ Board meetings ▪ Board financial expertise ▪ Expertise and Independence of audit committee ▪ Non- executive directors ▪ Social performance disclosure ▪ Effectiveness of CSR committees ▪ Public family business ▪ Nonfamily businesses
		External antecedents: ▪ Climate change ▪ Country regulation ▪ Stakeholders' orientation ▪ Industry factors ▪ Carbon institutions ▪ Government investment in low carbon projects	▪ Mimetic, and normative pressures ▪ Power distance ▪ Masculinity ▪ Uncertainty avoidance
	3.2 Emerging themes on outcomes	▪ ▪ Reporting quality ▪ Carbon disclosures ▪ Climate change disclosures ▪ Environmental disclosures	▪ Carbon reduction investments ▪ Investors' investment judgements ▪ Operating performance ▪ Carbon management ▪ Carbon performance

Appendix 24: Mapping carbon assurance themes with their contributors

Theme	Categories	Contributors	Frequency	% of studies
1. Definition of carbon assurance		Datt et al. (2018), Datt et al. (2019), Datt et al. (2020), Tang (2019)	4	8
2. Carbon assurance approaches	Approaches of carbon assurance	Green & Zhou (2013); Hay et al. (2023); Kazemian et al. (2022); Lodhia & Martin (2012); Simnett (2007); Tang & Luo (2014)	6	12
3. Emerging themes in carbon assurance literature	Antecedents of carbon assurance			
	External	Ascui (2014); Chatterjee (2012); Chithambo & Taurigana (2014); Comyns (2018); Green & Taylor (2013); Green & Li (2012); He et al. (2022); Huggin et al. (2011); Mateo-Márquez et al. (2020); Mia et al. (2019); Pitrakkos & Maroun (2018); Ratnatunga (2007); Rohani et al. (2023); Simnett et al. (2009); Zhou et al. (2016)	15	29
	Internal	Busch et al. (2023); Comyns & Figge (2015); Fan et al. (2021); He et al. (2022); Ioannou et al. (2016); Ryan & Tiller (2022); Simic et al. (2023); Simnett et al. (2010); Vera-Muñoz et al. (2020)	9	17
	Outcomes	Bui et al. (2021); Dutta, P. & Dutta, A. (2021); Luo et al. (2023); Mahmoudian et al. (2023); Tang & Demeritt (2018).	5	10

	Challenges	Ekasingh et al. (2019); Green et al. (2009); Kim et al. (2016); Knechel (2021); Matsumura et al. (2014); Martinov-Bennie & Hoffman (2012); Martinov-Bennie (2012); Simnett & Nugent (2007); Trotman & Trotman (2015); Tauringana & Chithambo (2015); Xu & Andrew (2021)	11	21
	Growth opportunities of carbon assurance	Moroney et al. (2012); Olson (2010)	2	4
			52	100
Theoretical underpinnings	Stakeholder	Bui et al. (2021); Chithambo & Taurigana (2014); Datt et al. (2018); Datt et al. (2019); Datt et al. (2020); Dutta, P. & Dutta, A. (2021); Pitrakkos & Maroun (2018); Simic et al. (2023); Luo et al. (2023); Mahmoudian et al. (2023); Moroney et al. (2012); Zhou et al. (2016).		
	Stakeholder-agency			
	Legitimacy	Datt et al. (2018); Datt et al. (2019); Datt et al. (2020); Olson (2010); Pitrakkos & Maroun (2018); Trotman & Trotman (2015)		
	Institutional	Comyns (2018); Datt et al. (2018); Mateo-Márquez et al. (2020); Matsumura et al. (2014); Tang (2019)		
	Signaling	Datt et al. (2018); Kazemian et al. (2022); Luo et al. (2023)		
	Credibility Enhancement	Luo et al. (2023)		
	Outside-in-management view	Luo et al. (2023); Rohani et al. (2023)		
	Carbon information asymmetry	Fan et al. (2021)		

Transition management	Tang (2019)