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Research article

Carbon Accounting: A Systematic Literature Review and Directions for Future Research

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Abstract: Carbon accounting is an evolving approach to support decision-making for climate action and reporting of progress. This systematic literature review of 27 journal articles in the field of carbon accounting provides an overview of the current state of the field. It illustrates the lack of transparency, reliability, and comparability within current measurement systems; the lack of research on how greenhouse gas inventories are linked to monitoring, decision-making, reporting and disclosure systems; and the role of the accounting profession. Based on the findings, we provide a summary of where research gaps exist and thus suggestions for future research directions.

Keywords: carbon accounting; accounting profession; measurement; sustainability accounting; GHG inventory; carbon budget; climate mitigation

JEL Codes: G3, M14, M41, M48, Q5, R5, L5

1. Introduction

There is now an urgent imperative for organizations and cities to help address climate change (IPCC, 2006; Isman et al., 2018; Salon et al., 2010). Accurate accounting of greenhouse gas emissions (GHGs) endeavor to inform decision-making on climate actions, budgeting, reporting and disclosure (Simpson, 2018; Greenhouse Gas Protocol, 2021b). Carbon accounting continues to be a growing approach to support mitigating climate change that more and more companies, governments, and organizations are pursuing to varying degrees (CDSB & SASB, 2019; CPA Canada, 2021; IFRS, 2017;

Linton et al., 2021; Sun et al., 2020). The topic of carbon accounting is relatively new to the field of accounting, having emerged in the last 10–20 years, though greenhouse gas measurement and inventories have existed for longer (Greenhouse Gas Protocol, 2021a; Salon et al., 2010). With the recent increase in demand for net-zero targets and pathways, accurate carbon accounting will be needed to ensure a standardized, transparent, and auditable approach (Value Reporting Foundation, 2021). Due to carbon accounting being an evolving topic, there is a growing need to increase clarity through enhanced research in this area.

The term, carbon accounting, has not been widely defined. This claim is supported by Stechemesser & Guenther (2012) who conclude that there is no comprehensive definition of carbon accounting available. However, through their semantic analysis, Stechemesser & Guenther (2012) define carbon accounting as follows: "carbon accounting comprises the recognition, the non-monetary and monetary evaluation and the monitoring of greenhouse gas emissions on all levels of the value chain and the recognition, evaluation and monitoring of the effects of these emissions on the carbon cycle of ecosystems" (Stechemesser & Guenther, 2012). In other words, carbon accounting considers inventories of GHGs, and the monitoring and decision-making related to mitigating and offsetting emissions. It potentially also includes monitoring climate impacts and related adaptation actions. This article is interested in organizational-level and city-level carbon accounting.

Two common methodologies used within carbon accounting include consumption-based emission inventories and production-based emission inventories. Kramers et al. (2013) state that the choice of whether to use consumption-based or production-based is one of the most fundamental decisions in accounting for emissions within a city. Studies support a large disparity of results between each option, with consumption-based resulting in a much higher emission value (Baltar de Souza Leão et al., 2020). Harris et al.'s (2020) summary of literature concludes that the ability to select production-based instead of consumption based, allows stakeholders to underestimate their impact on consumption. A common framing that incorporates both production and consumption-based emissions is scope 1, 2, and 3 emissions (Linton et al., 2022). Yet, typically these studies are only focused on the GHGs measurement and not on the other aspects of carbon accounting from an accounting perspective.

As the area of the research is relatively new to accounting, this study follows a qualitative systematic literature review (SLR) methodology approach (Popay et al., 2006). The SLR was chosen to identify what current research exists in the area of city-level and organizational-level carbon accounting; followed by, undergoing both an inductive and deductive analysis, with an overall goal of detecting the current conversations and gaps in the literature for identification of the future research needed to enhance understanding of carbon accounting. The study was driven by the following research questions: how transparent, reliable, and comparable measurement systems are in the carbon accounting field? how integrated are greenhouse gas inventories and monitoring, decision-making, reporting and disclosure systems? and what is the role the accounting profession has in carbon accounting?

2. Methods

SLR's proven ability to work well in practice will aid in achieving the objectives of this study, such as where Siemieniako et al. (2021) conduct a SLR to summarize the current state of their field of study through an extensive descriptive overview of the literature that exists in their area. The approach has been further proven, as Davis et al. (2014) note that through a SLR all available information will be located systematically and collated on an effect. Popay et al. (2006) explain that the use of evidence

synthesis in a SLR will aid in providing answers to what the current state of knowledge is in a certain area. A SLR enables the author to assess if an effect is constant over all studies and enables the identification of future studies that are needed in the area (Snyder, 2019).

The SLR completed follows the Popay et al. (2006) approach of a narrative synthesis. This approach pulls the evidence from the literature within the study to provide convincing conclusions and recommendations. Popay et al. (2006) discuss the need for a narrative synthesis approach when, unlike meta-analysis, there is a lack of understanding and no authoritative body of knowledge. Due to the nature of how new the research field surrounding carbon accounting is, the narrative synthesis is applied to this SLR on carbon accounting.

2.1. Information sources

Through a detailed title word search, a total of 27 relevant academic articles were obtained using the Scopus and ProQuest databases. Scopus and ProQuest were selected as databases due to their vast access to academic literature. Scopus is the main database in support of the Research Intelligence portfolio and is noted to be the preferred database for academic researchers that provides "unparalleled and continuous access to critical research output from around the world" (Elsevier, 2021). ProQuest is a credible scholarly database that is relied on by 99% of the top 400 universities globally; the database includes content that spans disciplines, time, and geography (ProQuest, 2021).

The keyword strings used in a title search for both databases are outlined in section 2.3, illustrating the number of results, replications, and duplications within each database. Each search result was reviewed through an assessment of title, abstract and where necessary a full review to assess relevancy. Relevancy was determined based on the details provided in section 2.3 below.

2.2. *Inclusion/exclusion criteria*

The study focused on city-level and organizational-level carbon accounting, including budgeting and targets. Information sources included journal articles exclusively, and therefore excluded book chapters, thesis papers, reports, and industry documents from public and private organizations. There were no constraints on geography or discipline of the study, as the study seeks to provide the research that is available globally in English within the database search undertaken.

2.3. *Keyword search and screening results*

Several keywords and strings were selected that were identified as relevant to the research question defined in the study. The following first 7 strings were all paired with string 8 using a title search to identify relevant literature:

1. "climate AND budget*" OR "carbon AND budget*" OR "emission* AND budget*"
2. "climate AND measure*" OR "carbon AND measure*" OR "emission* AND measure*" OR "climate AND budget* AND measure*" OR "carbon AND budget* AND measure*" OR "emission* AND budget* AND measure*"
3. "account* AND for AND carbon" OR "account* AND for AND climate" OR "account* AND for AND emission*" OR "climate AND accounting" OR "carbon AND accounting" OR "emission* AND accounting"

4. “climate AND target*” OR “carbon AND target*” OR “emission* AND target*”
5. “climate AND baseline*” OR “carbon AND baseline*” OR “emission* AND baseline*”
6. “energy AND finance*” OR “energy AND accounting”
7. “green AND budget*” OR “green AND accounting”
8. +AND “city” OR “cities” OR “town*” OR “municipalit*” OR “region*” OR “communit*” OR “organization*” OR “business*” OR “ltd.” OR “npo*” OR “non-profit*” OR “ngo*” OR “Compan*”

To implement effective screening, all literature results were first assessed based on title and abstract followed by a full review of the article to assess relevancy. Relevancy was determined based on the professional judgement of the authors, defined as a clear relation to the research question identified within the study.

Based on the title keyword search conducted on May 28, 2021, 422 results were obtained, 184 from Scopus and 238 from ProQuest. Through screening, there were 27 items of literature that were assessed to meet the objective of the research question defined and 395 noted as irrelevant. Results are shown in Figure 1. Excluded items within the title and abstract review included 20 duplicates and/or repeated items.

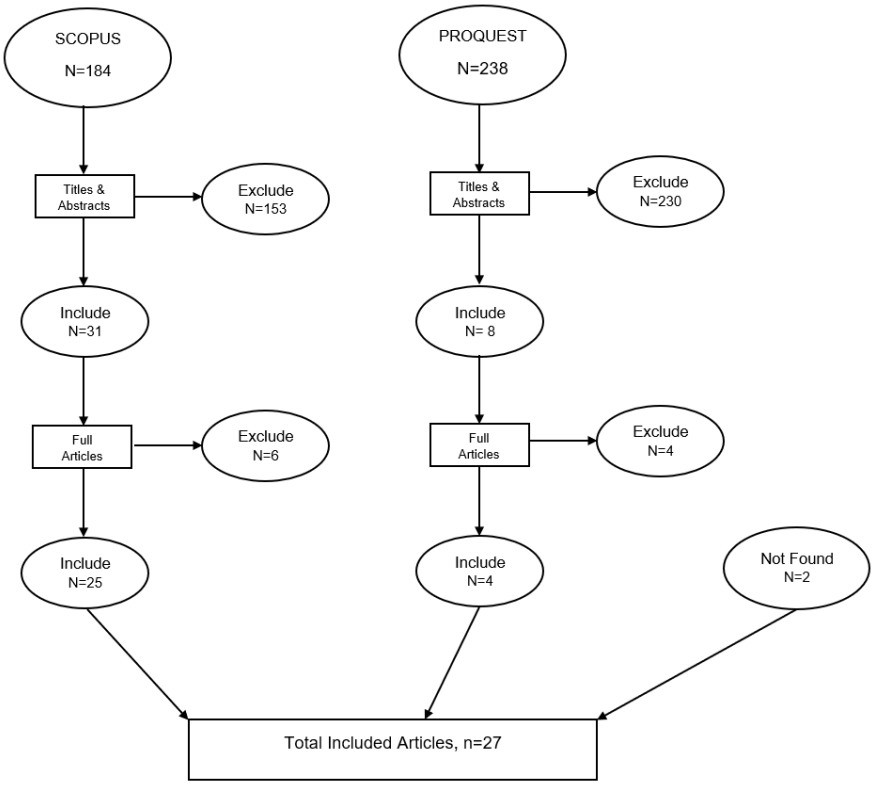

Figure 1. Search and screening results.

As shown in Figure 1, 39 articles were included after the title and abstract review, however, during the detailed full review of relevant articles obtained, 10 additional items were excluded, five did not meet the definition of being an article and five were determined to be out of scope as they did not focus on city-level or organizational-level carbon accounting. Two articles were unable to be obtained as they were only available in hard copy at a location not accessible to the authors.

2.4. *Literature coding*

Through identification of the research that exists in the area using the approach outlined in section 2.3 above, the 27 articles selected in the SLR were coded using NVivo. The coding process followed both a deductive and inductive approach.

The deductive approach used a predefined list of descriptive codes, such as the journal publication and year of publication, to aid in an understanding of a current overview of the research being published.

A full inductive thematic approach was taken to identify the themes that were in the literature. Popay et al. (2006) outlines the thematic analysis as a way to systematically identify the important reoccurring themes through a review of literature without a clear predefined list to extract data, but rather identify themes through pulling together similar concepts and findings across the literature. Through the authors knowledge in the carbon accounting field, sub questions were developed to aid in guiding the thematic analysis and were used to aid in identifying reoccurring themes.

- Sub-question 1: Is there measurement certainty in the field of carbon accounting?
- Sub-question 2: What level of governance and policy guidance exists in the field of carbon accounting?
- Sub-question 3: What is the role of accountants in the field of carbon accounting?
- Sub-question 4: What are the research gaps in the field of carbon accounting?

The approach outlined enabled the coding process to explore and identify the major themes across the SLR.

3. Literature analysis and results

The SLR included 27 published journal articles in the field of carbon accounting, including budgeting and targets. The title word string search produced eight articles from the Journal of Cleaner Production, three articles from Energy Policy and six from journals with the term accounting within the journal name. See Figure 2.

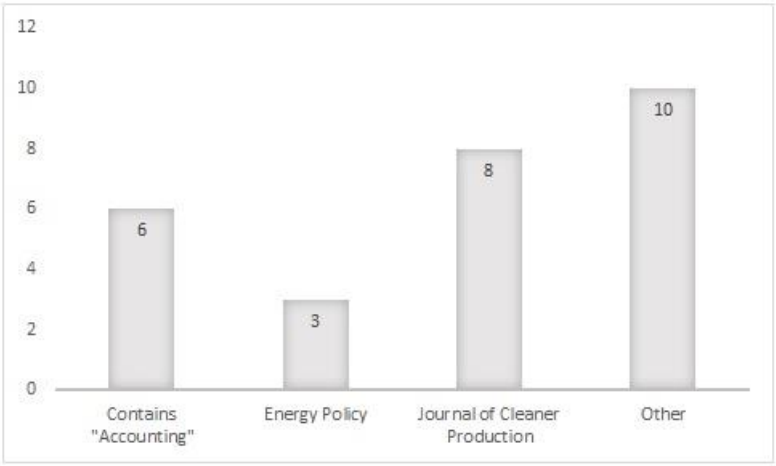

Figure 2. Distribution of articles published in the field of carbon accounting among journals.

Research in carbon accounting, is a new area that has only recently began to gain momentum. This is illustrated through the year of publication of the 27 articles, all of which were within the last 13 years. See Figure 3. As indicated in Figure 3, more than 50% of the literature has been published within the last 5 years.

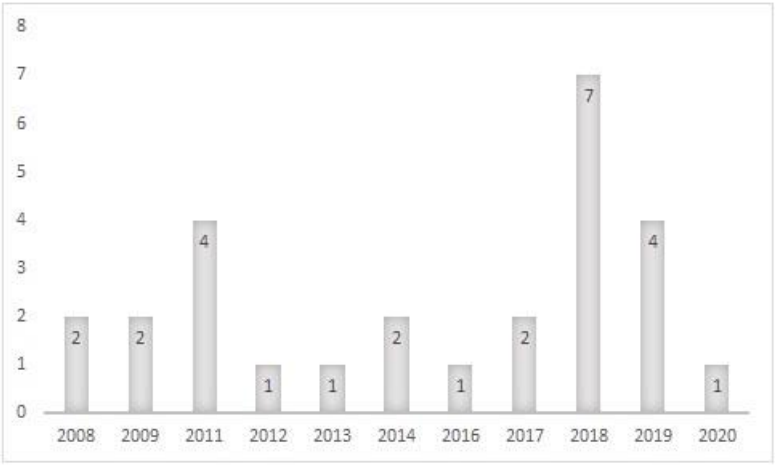

Figure 3. Year of articles published in the field of carbon accounting among journals.

Articles published consist of authors from 12 countries that span much of the globe including seven from China, four from the United Kingdom and three from the United States of America. For this analysis, only the location of the first author's institution was used. Each article was coded separately. See Table 1.

Table 1. Author's Domicile.

Country	#
China	7
United Kingdom (UK)	4
United States of America (USA)	3
Australia	2
Brazil	2
Canada	2
Sweden	2
France	1
Germany	1
Japan	1
Italy	1
UAE	1

Research conducted also spans across much of the globe as outlined in Table 2. The table also illustrates that more than 50% of the articles were focused on research within one country.

Table 2. Country of Research.

Country	#
China	6
Australia	1
Brazil	1
Canada	1
France	1
Germany	1
Malaysia	1
UK	1
USA	1
Multiple	9
General	4

3.1. Major themes

Throughout the review of the 27 articles, overarching themes were identified through inductive coding, following a narrative synthesis approach outlined by Popay et al. (2006). Through consideration of the sub-questions outlined and identifying reoccurring results within the SLR, several themes have been identified and supported within this study.

The supported themes consist of the (i) increasing carbon emissions seen across the globe, (ii) carbon accounting faces a critical amount of measurement uncertainty, (iii) there is a lack of ability to compare reporting results, (iv) there is a need for the implementation of policy and integrated procedures surrounding carbon accounting and (v) there is immense opportunity for the accounting profession to act to make a difference within the field of carbon accounting.

3.1.1. Increasing carbon emissions

During the SLR several instances conclude that carbon emissions are increasing across the globe. Within the literature review of Liu et al. (2015), it outlines a study looking at aggregate CO_2 emissions published by Du et al. (2012), which confirms emissions have been on the rise in all provinces assessed within China since 1995. Le Breton and Aggeri (2018) equate the results of their study to the constant in increasing GHGs being experienced across the globe and Wang and Chen (2018) attribute the increase in carbon emissions currently seen to the accelerating urbanization and highlights the strong need for climate mitigation to be implemented. Fong et al. (2008) state that emissions across Malaysia have been increasing without regard to the city size and conclude that without aggressive action, by 2050 there could be emissions seven times their current levels.

With the rise in carbon emissions illustrated, the literature also supports the need to act in unity. Livermore (2019) highlights the importance of the need for allegiance in the fight against the climate crisis noting "In a sense, all the countries in the world are in a car together, with each country and its component organizations having a foot on the accelerator, speeding toward a cliff—a climate tipping point. If we go over, we go over together, and we all lose" (Livermore, 2019).

3.1.2. Measurement uncertainty

Majority of the literature within the SLR highlights the vast uncertainty surrounding the measurement within carbon accounting. Bowen and Wittneben (2011) notes the tension in accuracy and consistency within carbon accounting, and Sperling and Ramaswami (2018) note the patterns of inconsistency in the methodologies of carbon accounting for cities.

Under-counting emissions is of concern. Harris et al.'s (2020) study had to scope out emission measurement from many items due to lack of data available for water, waste, and agriculture, which if was included, would change their results. José Célio Silveira Andrade et al. (2018) study concludes that if urban supply chains and final consumers were taken into account for the GHGs measured, the GHGs inventories reported for Madrid may be twice of what was reported.

- Defining boundaries

Kennedy and Sgouridis (2011) state that it is essential to clarify boundaries to monitor and manage urban carbon emissions and Kramers et al. (2013) note that there are different system boundaries that exist for different cities increasing the complexity of carbon accounting. Chen et al. (2019) highlight that many protocols being used in city carbon accounting include different requirements for out-of-boundary emissions that impact in-boundary activities that skew results, concluding that within the same city a change in protocols can lead to a different result.

Haslam et al. (2014) discuss the difficulty due to the great amount of judgment that is needed when defining boundaries in determining whether or not the emissions should be included based on the ownership, control or the overall responsibility which leads to a lack of reconciliation consistency. Chen et al. (2019) use scope 1, 2 and 3 emissions as a way to help illustrate uncertainty within boundaries.

- Consumption-based versus production-based inventories

Two common methodologies used within carbon accounting include consumption-based emission inventories (CB) and production-based emission inventories (PB). José Célio Silveira Andrade et al. (2018) summarize the definition of PB as an allocation of GHGs to producers and CB as an allocation of GHGs to consumers. Kramers et al. (2013) state that the choice of whether to use CB or PB as one of the most fundamental decisions in accounting for emissions within a city.

Baltar de Souza Leão et al. (2020) conclude that existing studies that assess CB versus PB found that depending on the city's economic profile, CB results in a much higher value. This is supported through Harris et al.'s (2020) summary of literature that highlights a large disparity when comparing CB versus PB, as CB allows stakeholders to underestimate the impact on consumption as there is flexibility that increases risk of bias. Harris et al. (2020) went on to support the differences between CB and PB through noting the study by Meng et al. (2017) that compares CB and PB in Beijing, Shanghai, Tianjin and Chongqing, and Sudmant et al. (2018) who examine CB and PB in China, United Kingdom and USA; both studies conclude that most cities result in a higher emissions when using CB rather than PB. Based on one study, Beijing's CO_2 emissions were 1.47 times higher under CB (Xue et al., 2019) and Harris et al.'s (2020) study concludes that CB emissions were twice as much as PB on average.

Chen et al. (2019) discuss the scope 1, 2 and 3 emissions under different methods and provide a recommendation to avoid adding up scope 2 and 3 as there is a risk of double counting within the boundary "since one city's imports can be another city's exports" (Chen et al., 2019, p. 5549). In comparison, instances of under-counting emissions are occurring under PB. For example, as Harris et al. (2020) noted an exclusion of PB emissions related to agriculture, waste and water within scope 1 and 2 due to a lack of data available.

Chen et al. (2019) determine that even though CB is an option, it is not being used as often as the alternatives as it is found to be quite complex and lacks data to enable application. With the known lack of data, increased complexity and less favorable results of CB, Chen et al. (2019) conclude CB is not as commonly used as the PB alternative. With the large differences between the use of PB versus CB, where Harris et al.'s (2020) study concludes that CB emissions could be twice as much compared to PB, it easy to conclude that if given the choice, many will prefer to use PB.

- Gaps identified

Baltar de Souza Leão et al. (2020) note that even though there are multiple studies published on methods to improve the accuracy of carbon accounting, there still exists the risk of inventory uncertainty. Baltar de Souza Leão et al. (2020) highlight the two main reporting gaps for carbon accounting are incompleteness and a lack of transparency.

Baltar de Souza Leão et al. (2020) support the first gap relating to incompleteness as it was found that in their study within Brazil, some GHGs inventories did not include emissions related to some economic sectors; the second gap relating to transparency was supported noting a lack of backing for the input data, emission factors or how it was measured, therefore making it impossible to verify or replicate.

Baltar de Souza Leão et al. (2020) quote that a study by Parvez et al. (2019), which assess 24 mega cities' GHGs disclosures, has results that were consistent with theirs, as the research also concludes that inventories were incomplete by not including all emission sources in their measurement and there is a lack of transparency.

3.1.3. Comparability shortcomings

Due to the measurement uncertainty supported within the above section, carbon accounting inventories and disclosures are not comparable. Kramers et al. (2013) note multiple obstacles that make comparability of carbon accounting related to a city's target setting difficult, including the difference in boundaries used, incomplete data availability, and lack of knowledge within administration.

Many alternative decisions around the approach exist for carbon accounting in addition to just considering CB versus PB approaches, as 13 of the 27 articles within the SLR use, apply or recommend an alternative or approach to accounting for carbon, such as FML Model illustrated by Fong et al. (2008), the Social Accounting Matrix (SAM) price model illustrated by Xue et al. (2019), the input-output approach illustrated by Liu et al. (2015), Wang et al. (2018) and Pulselli et al. (2019), the three tier and Economic Input-Output Life Cycle Assessment (EIO-LCA) illustrated by Song et al. (2012) and Mahmoudian et al. (2021) use data collected by CDP (formerly known as Carbon Disclosure Project). Each alternative presents a different approach to measurement and thus may result in a different outcome.

3.1.4. Need for policy and integrated decision-making, budgeting, reporting and disclosure procedures

Livermore (2019) quotes Peter Drucker who is known for often saying "What gets measured gets managed", which Livermore (2019) conclude to be highly relevant when considering the invisible carbon emissions, as there is a need to ensure they are quantified and effectively managed.

Salon et al. (2010) note that many cities have climate action plans, however, most include a high level of voluntary guidance versus mandatory implementation. Mandatory policies have been proven to be effective in a number of instances outlined within the literature review by Salon et al. (2010).

In their literature review, Bowen and Wittneben (2011) draw out conclusions based on the article from Randjelovic et al. (2003), and note a need for governments to act though implementing carbon reduction measures, a need for regulatory measures to be implemented to encourage investment and a need to reduce consumption towards decreased climate impacts.

- Reporting need for policy and integration

Baltar de Souza Leão et al. (2020) note that there is a clear lack of transparency in 20 GHGs reports on inventory reviews surrounding assumptions, data, emission factors measurement and overall limitations. Kennedy and Sgouridis (2011) conclude that due to the lack of clarity surrounding defining terms of carbon accounting, there is a lack of usefulness to be able to quantify targets and clarification of boundaries is needed for effective monitoring and management of carbon emissions.

Mahmoudian et al. (2021) note that there is limited research assessing the correlation of GHGs performance and GHGs reporting. Baltar de Souza Leão et al. (2020) find that research on the quality analysis of GHGs reporting from cities is rare. Burritt et al. (2011) literature review states that practice undertaken at the corporate level on collecting, managing and the communication of carbon related information is limited and little research has been done on sustainability management accounting related to practical implementation. José Célio Silveira Andrade et al. (2018) note that evidence of a city's carbon footprint is scarce.

Le Breton and Aggeri (2018) discuss that France passed a law in 2012 requiring major listed companies to disclose at least one indicator of carbon within their external reporting. This may allow for increased risk of bias, as the company can select which to disclose, therefore only disclosing the indicator that highlights their results in a favorable manner (Le Breton & Aggeri, 2018). Jia et al. (2018) determine the need for government to act and support research to advance the understanding of monitoring and verification of emissions.

3.1.5. Accounting professionals' ability to contribute

Accountants are recognizing the opportunity to be a contender in the field of carbon accounting as Lovell and Mackenzie (2012) note the technical working group for the Climate Disclosure Standards Board (Board) is largely made up of accountants, with the Board focused on the development of international voluntary carbon reporting standards. Engels (2009) note that big four accounting firms, Deloitte and PWC, are active in the development and shaping of the field surrounding carbon accounting requirements and Cook (2009) note the IASB (International Accounting Standards Board) is actively seeking to embed carbon accounting into current accounting practice.

Mahmoudian et al. (2021) highlight that accountants will take on a leading role related to GHGs challenges and their financial expertise will aid in supporting strategic initiatives towards reducing GHGs. Engels (2009) find through their qualitative study, specialized private consulting firms are the constant leading source of expertise pursued by companies for obtaining advice towards carbon accounting.

José Célio Silveira Andrade et al. (2018) conclude that it is crucial toward effective environmental management strategies that city-level carbon accounting standards are developed to aid in development of effective environmental policies. Engels (2009) also conclude that a system to reporting CO_2 is needed, and to both understand and compare carbon accounting, a generic and comprehensive framework is critical.

Bowen and Wittneben (2011) support that accounting tools are not fully developed for reporting on carbon emissions, but there is an opportunity present as accountants have adequate experience and

knowledge to embrace the uncertainty within climate accounting through tools available, such as sensitivity analysis and hedging.

Chen et al. (2019) concludes that there is a need to prioritize future research towards understanding and defining standards in carbon accounting to support practitioners and Engels (2009) notes the need for more qualitative research to understand how companies learn to do carbon accounting and the three tier model should be researched from an urban carbon accounting perspective. Mahmoudian et al. (2021) acknowledge there has been little research focused on carbon disclosure using the CDP database to assess the association between carbon disclosure and performance.

4. Conclusions and future research directions

Carbon emissions are continuing to rise across the globe. The need to act is now, as without action we will continue to see a surge in carbon emissions worldwide (IPCC, 2006). This systematic literature review of research conducted in numerous different countries illustrates that carbon accounting is a key procedure for inventorying GHGs, and then embedding that information into decision-making, budgeting, and reporting systems. As identified through this thematic summary of the literature conversations, numerous gaps remain.

4.1. Identified gaps and future research direction

Building on the categories found through the inductive thematic results, suggestions for areas of future research are detailed here.

4.1.1. Relevance of carbon accounting to addressing increasing carbon emissions

The importance of addressing climate change is well understood. The extent that city-level and organizational-level carbon accounting is already playing a role in the measurement systems, reporting and disclosure systems, and even decision-making systems is less understood. Which accounting procedures are key to ensuring accurate, and transparent measurement, reporting and disclosure? How can assurance be added to these systems? How can carbon accounting support green bonds and other climate finance mechanisms? How is carbon disclosure relevant to financial stakeholders? Do carbon accounting, reporting and disclosure systems actually improve decision-making and climate mitigation progress?

4.1.2. Measurement uncertainty and comparability

GHGs inventories are often determined to be incomplete across the globe due to a lack of data available, which is one of the many reasons outlined in the study of why carbon accounting has a high amount of measurement uncertainty. Due to the uncertainty, there is an inability to compare results of carbon accounting as there is no one specific way to account for carbon emissions, such as how to determine the boundaries or the framework to apply. The result is a lack of comparability, transparency, and reliability as there is an increased risk of bias to strategically select a carbon accounting approach that is most economical, efficient or showcases the entity or region in a positive light. Further research could determine accessible data and the most relevant indicators and science-based measurement

techniques that are emerging from practice, and how these can best inform standardized city-level and organizational-level reporting and disclosure. Also, what should the organizational boundaries be for net-zero carbon accounting to avoid double-counting by numerous organizations? How should carbon sequestering and sinks be calculated in these accounting systems?

4.1.3. Policy and regulation

Due to the current regulation and policy for external reporting of carbon emissions, there is an ability for companies and organizations to only highlight their strengths versus their weaknesses. Thus, there is an inability to be confident in the accuracy of carbon accounting measurement within reports, therefore, limiting their ability to be useful or comparable. What government policy is most effective for incentivizing standardized, transparent, and reliable reporting and disclosure for accounting for carbon?

4.1.4. Links between city-level and organizational-level GHGs measurement, budgeting, decision-making, reporting and disclosure

Carbon accounting is much broader than measurement, though much of the current research is still focused on this step. Even with accurate data on GHGs, how can that information best be integrated into decision-making processes, including budgeting decisions, to ensure that the organization is effectively integrating a climate lens into all relevant decisions? How does GHGs reporting link to financial reporting? How can climate-related financial disclosure be reliable enough to be audited by a third-party? Is it possible to link decisions to how much of the organization's remaining carbon budget will be used in this fiscal year? How can scenarios be used to project how climate actions will reduce carbon emissions over time, and reach net-zero by 2050 or sooner?

Sustainable development has long understood the need to consider social, ecological and economic considerations in an integrated way. How can carbon accounting incorporate social equity or other social sustainability indicators within decision-making systems to ensure that climate action does not result in furthering social concerns?

4.1.5. Climate impacts, adaptation and risk

Risk assessment and disclosure of climate risk is an important topic. It is directly tied to carbon accounting, and yet the emphasis of the literature found under the title carbon accounting had a strong emphasis on mitigation. How can organizations account for both risk/resilience and action/mitigation in their carbon accounting, including measurement, decision-making, reporting and disclosure?

4.1.6. The role of the accounting profession

The big four accounting firms, and IASB are already actively seeking to embed carbon accounting into current accounting practice. What training is needed for professional accountants on carbon accounting? What guidance is needed for an organization to best embed carbon accounting in their measurement, budgeting, decision-making, reporting and disclosure systems? Which approaches to dissemination have been most effective? What are the barriers to adoption?

4.2. Limitations and future research directions

The systematic literature review performed is based on the approach presented in Section 2. As with any systematic literature review, there are limitations introduced through the design. Thus, the gaps identified in the categories above may not illustrate a definitive depiction of literature available globally. Specifically, potential limitations are a result of: the title word search; the use of two databases including a language constraint; and, the search criteria used. These gaps we have identified highlight understudied areas, but this does not mean they are unstudied by authors in other disciplines, writing in other languages, or using other terminology. We encourage others to look deeper at keywords such as disclosure and reporting, for example.

To illustrate, additional research not captured include existing literature on the following gaps: relevance of carbon accounting addressing increasing carbon emissions (Griffin et al., 2017; Matsumura et al., 2014); measurement uncertainty and comparability (Dragomir, 2012; Wegener et al., 2019); policy and regulation (European Union, 2013; Greenhouse Gas Protocol, 2021a; Value Reporting Foundation, 2021); links between city-level and organizational-level GHGs measurement, budgeting, decision-making, reporting and disclosure and the role of the accounting profession (Knox, 2014; Lippert, 2015; Vesty et al., 2015).

In closing, these emerging research directions offer high level thoughts on emerging research needs related to carbon accounting. Leading companies, governments, and organizations are thinking about these topics and they proactively work to address climate change and provide the accounting systems needed to support that. Researchers have the potential to help design these systems, evaluate their effectiveness, and disseminate best practice. Climate change is global, and so must this effort to update accounting systems to incorporate carbon accounting.

Conflict of interest

All authors declare no conflicts of interest in this paper.

References

Andrade JCS, Dameno A, Pérez J, et al. (2018) Implementing city-level carbon accounting: A comparison between Madrid and London. *J Clean Prod* 172: 795–804. https://doi.org/10.1016/j.jclepro.2017.10.163

Baltar de Souza Leão E, do Nascimento LFM, Andrade JCS, et al. (2020) Carbon accounting approaches and reporting gaps in urban emissions: An analysis of the greenhouse gas inventories and climate action plans in Brazilian cities. *J Clean Prod* 245. https://doi.org/10.1016/j.jclepro.2019.118930

Bowen F, Wittneben B (2011) Carbon accounting: Negotiating accuracy, consistency and certainty across organisational fields. *Account Audit Account J* 24: 1022–1036. https://doi.org/10.1108/09513571111184742

Burritt RL, Schaltegger S, Zvezdov D (2011) Carbon management accounting: Explaining practice in leading German companies. *Aust Account Rev* 21: 80–98. https://doi.org/10.1111/j.1835-2561.2010.00121.x

Simpson P (2018) How environmental disclosure fuels greater ambition. Available from: https://www.cdp.net/en/articles/companies/earth-day-how-environmental-disclosure-fuels-greater-ambition.

Climate Disclosure Standards Board (CDSB), Sustainability Accounting Standards Board (SASB) (2019) TCFD implementation guide. Available from: https://www.sasb.org/knowledge-hub/tcfd-implementation-guide/.

Chen G, Shan Y, Hu Y, et al. (2019) Review on city-level carbon accounting. *Environ Sci Technol* 53: 5545–5558. https://doi.org/10.1021/acs.est.8b07071

Cook A (2009) Emission rights: From costless activity to market operations. *Account Org Soc* 34: 456–468. https://doi.org/10.1016/j.aos.2007.12.001

CPA Canada (2021) Business and accounting resources: Sustainability reporting updates. Available from: https://www.cpacanada.ca/en/business-and-accounting-resources/financial-and-non-financial-reporting/sustainability-environmental-and-social-reporting/publications/sustainability-reporting-updates.

Davis J, Mengersen K, Bennett S, et al. (2014) Viewing systematic reviews and meta-analysis in social research through different lenses. *Springerplus* 3: 1–9. https://doi.org/10.1186/2193-1801-3-511

Dragomir VD (2012) The disclosure of industrial greenhouse gas emissions: a critical assessment of corporate sustainability reports. *J Clean Prod* 29–30: 222–237. https://doi.org/10.1016/J.JCLEPRO.2012.01.024

Du L, Wei C, Cai S (2012) Economic development and carbon dioxide emissions in China: Provincial panel data analysis. *China Econ Rev* 23: 371–384. https://doi.org/10.1016/J.CHIECO.2012.02.004

Elsevier (2021) Scopus: Who Uses Scopus. Available from: https://www.elsevier.com/solutions/scopus/who-uses.

Engels A (2009) The European emissions trading scheme: An exploratory study of how companies learn to account for carbon. *Account Org Soc* 34: 488–498. https://doi.org/10.1016/j.aos.2008.08.005

European Union (2013) EUR-Lex. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013L0034.

Fong WK, Matsumoto H, Lun YF (2008) Establishment of city level carbon dioxide emission baseline database and carbon budgets for developing countries with data constraints. *J Asian Archit Build Eng* 7: 403–410. https://doi.org/10.3130/jaabe.7.403

Greenhouse Gas Protocol (2021a) Greenhouse Gas Protocol: About us. Available from: https://ghgprotocol.org/about-us.

Greenhouse Gas Protocol (2021b) Greenhouse Gas Protocol: Corporate standard. Available from: https://ghgprotocol.org/corporate-standard.

Griffin PA, Lont DH, Sun EY (2017) The Relevance to investors of greenhouse gas emission disclosures. *Contemp Account Res* 34: 1265–1297. https://doi.org/10.1111/1911-3846.12298

Harris S, Weinzettel J, Bigano A, et al. (2020) Low carbon cities in 2050? GHG emissions of European cities using production-based and consumption-based emission accounting methods. *J Clean Prod* 248: 119206. https://doi.org/10.1016/j.jclepro.2019.119206

Haslam C, Butlin J, Andersson T, et al. (2014) Accounting for carbon and reframing disclosure: A business model approach. *Account Forum* 38: 200–211. https://doi.org/10.1016/j.accfor.2014.04.002

IFRS (2017) IFRS-IASB chair's speech: The times, they are a-changin'. Available from: https://www.ifrs.org/news-and-events/news/2017/09/iasb-chairmans-speech-the-times-the-are-achangin/.

IPCC (2006) 2006 IPCC guidelines for national greenhouse gas inventories. Available from: https://www.ipcc.ch/report/2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/.

Isman M, Archambault M, Racette P, et al. (2018) Ecological footprint assessment for targeting climate change mitigation in cities: A case study of 15 Canadian cities according to census metropolitan areas. *J Clean Prod* 174: 1032–1043. https://doi.org/10.1016/j.jclepro.2017.10.189

Jia J, Gong Z, Chen C, et al. (2018) Urban carbon dioxide equivalent (CO_2e) accounting based on the GPC framework: A case of the underdeveloped city of Nanchang, China. *Int J Climate Change Strat Manage* 10: 812–832. https://doi.org/10.1108/IJCCSM-03-2017-0074

Kennedy S, Sgouridis S (2011) Rigorous classification and carbon accounting principles for low and zero carbon cities. *Energy Policy* 39: 5259–5268. https://doi.org/10.1016/j.enpol.2011.05.038

Knox H (2014) Footprints in the City: models, materiality, and the cultural politics of climate change. *Anthropol Quart* 87: 405–431.

Kramers A, Wangel J, Johansson S, et al. (2013) Towards a comprehensive system of methodological considerations for cities' climate targets. *Energy Policy* 62: 1276–1287. https://doi.org/10.1016/j.enpol.2013.06.093

Le Breton M, Aggeri F (2018) Counting before acting? The performativity of carbon accounting called into question-calculation acts and dispositifs in a big French construction company. *Management* 21: 832–855. https://doi.org/10.3917/mana.212.0834

Linton S, Clarke A, Tozer L (2021) Strategies and governance for implementing deep decarbonization plans at the local level. *Sustainability* 13: 154. https://doi.org/10.3390/su13010154

Linton S, Clarke A, Tozer L (2022) Technical pathways to deep decarbonization in cities: Eight best practice case studies of transformational climate mitigation. *Energy Res Soc Sci* 86: 102422. https://doi.org/10.1016/J.ERSS.2021.102422

Lippert I (2015) Environment as datascape: Enacting emission realities in corporate carbon accounting. *Geoforum* 66: 126–135. https://doi.org/10.1016/J.GEOFORUM.2014.09.009

Liu LC, Liang QM, Wang Q (2015) Accounting for China's regional carbon emissions in 2002 and 2007: production-based versus consumption-based principles. *J Clean Prod* 103: 384–392. https://doi.org/10.1016/j.jclepro.2014.07.009

Livermore J (2019) What's your organization's carbon budget? *Nat Gas Electricity* 36: 1–10. https://doi.org/10.1002/gas.22147

Lovell H, Mackenzie D (2012) Accounting for carbon: The role of accounting professional organisations in governing climate change. In Newell P, Boykoff M, Boyd E, *The New Carbon Economy*, John Wiley and Sons, 107–133. https://doi.org/10.1002/9781118315835.ch6

Mahmoudian F, Lu J, Yu D, et al. (2021) Inter-and intra-organizational stakeholder arrangements in carbon management accounting. *British Account Rev* 53: 100933. https://doi.org/10.1016/j.bar.2020.100933

Matsumura EM, Prakash R, Vera-Muñoz SC (2014) Firm-value effects of carbon emissions and carbon disclosures. *Account Rev* 89: 695–724. https://doi.org/10.2308/ACCR-50629

Meng J, Mi Z, Yang H, et al. (2017) The consumption-based black carbon emissions of China's megacities. *J Clean Prod* 161: 1275–1282. https://doi.org/10.1016/J.JCLEPRO.2017.02.185

Parvez M, Hazelton J, James G (2019) Greenhouse gas emissions disclosure by cities: The expectation gap. *Sustain Account Manage Policy J* 10: 685–709. https://doi.org/10.1108/SAMPJ-11-2017-0138

Popay J, Roberts H, Sowden A, et al. (2006) Guidance on the conduct of narrative synthesis in systematic reviews: A product from the ESRC methods programme. Available from: https://www.lancaster.ac.uk/media/lancaster-university/content-assets/documents/fhm/dhr/chir/NSsynthesisguidanceVersion1-April2006.pdf.

ProQuest (2021) Academic: Credible, Authoritative Resources that Inspire and Engage. Available from: https://about.proquest.com/en/libraries/academic/.

Pulselli RM, Marchi M, Neri E, et al. (2019) Carbon accounting framework for decarbonisation of European city neighbourhoods. *J Clean Prod* 208: 850–868. https://doi.org/10.1016/j.jclepro.2018.10.102

Salon D, Sperling D, Meier A, et al. (2010) City carbon budgets: A proposal to align incentives for climate-friendly communities. *Energy Policy* 38: 2032–2041. https://doi.org/10.1016/j.enpol.2009.12.005

Siemieniako D, Kubacki K, Mitrega M (2021) Inter-organisational relationships for social impact: A systematic literature review. *J Bus Res* 132: 453–469. https://doi.org/10.1016/j.jbusres.2021.04.026

Snyder H (2019) Literature review as a research methodology: An overview and guidelines. *J Bus Res*104: 333–339. https://doi.org/https://doi.org/10.1016/j.jbusres.2019.07.039

Song D, Su M, Yang J, et al. (2012) Greenhouse gas emission accounting and management of low-carbon community. *Sci World J* 2012. https://doi.org/10.1100/2012/613721

Sperling JB, Ramaswami A (2018) Cities and "budget-based" management of the energy-water-climate nexus: Case studies in transportation policy, infrastructure systems, and urban utility risk management. *Environ Prog Sustain Energy* 37: 91–107. https://doi.org/10.1002/ep.12765

Stechemesser K, Guenther E (2012) Carbon accounting: A systematic literature review. *J Clean Prod* 36: 17–38. https://doi.org/10.1016/J.JCLEPRO.2012.02.021

Sudmant A, Gouldson A, Millward-Hopkins J, et al. (2018) Producer cities and consumer cities: Using production- and consumption-based carbon accounts to guide climate action in China, the UK, and the US. *J Clean Prod* 176: 654–662. https://doi.org/10.1016/J.JCLEPRO.2017.12.139

Sun X, Clarke A, MacDonald A (2020) Implementing community sustainability plans through partnership: Examining the relationship between partnership structural features and climate change mitigation outcomes. *Sustainability* 12: 6172. https://doi.org/10.3390/su12156172

Value Reporting Foundation (2021) Value Reporting Foundation. Available from: https://www.valuereportingfoundation.org/.

Vesty GM, Telgenkamp A, Roscoe PJ (2015) Creating numbers: carbon and capital investment. *Audit Account J* 28: 302–324. https://doi.org/10.1108/AAAJ-10-2013-1507

Wang S, Chen B (2018) Three-Tier carbon accounting model for cities. *Applied Energy* 229: 163–175. https://doi.org/10.1016/j.apenergy.2018.07.109

Wang Z, Li Y, Cai H, et al. (2018) Comparative analysis of regional carbon emissions accounting methods in China: Production-based versus consumption-based principles. *J Clean Prod* 194: 12–22. https://doi.org/10.1016/j.jclepro.2018.05.018

Wegener M, Labelle R, Jerman L (2019) Unpacking carbon accounting numbers: A study of the commensurability and comparability of corporate greenhouse gas emission disclosures. *J Clean Prod* 211: 652–664. https://doi.org/10.1016/J.JCLEPRO.2018.11.156

Xue MM, Liang QM, Wang C (2019) Price transmission mechanism and socio-economic effect of carbon pricing in Beijing: A two-region social accounting matrix analysis. *J Clean Prod* 211: 134–145. https://doi.org/10.1016/j.jclepro.2018.11.116

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