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Developing circular accounting for carbon emissions measurement in Indonesia: a literature review

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Abstract
This study aims to develop carbon footprint measurements using attribution and consequential methods. Attribution and consequential methods have been widely implemented in Europe and America. Carbon emission sources are classified based on consumption and production activity categories. However, in Indonesia, forest and land fires are the highest source of carbon emissions, occurring almost every year during the dry season in peatlands. Peatland exploitation leads to forest fires and deforestation of tropical forests in Indonesia. The impacts of these fires include the loss of ecosystem benefits and biodiversity. Peatlands in Indonesia are estimated to produce 68.6 gigatons of carbon, equivalent to 10% to 14% of the world's organic carbon sources. Accounting methods can be used to measure and report carbon emissions caused by forest and land fires. This study used a systematic literature review. The literature used comes from carbon accounting experts in the UK, published in Scopus-indexed journals. The study results show that attribution and consequential methods could be used to measure the carbon footprint caused by peatland exploitation. The Indonesian government could adopt this method in developing circular accounting for carbon emission measurement and reporting.

Keywords: Carbon Accounting, Consequential Methods, Attributional Methods.

Abstrak
Penelitian ini bertujuan untuk membangun pengukuran jejak karbon menggunakan metode atribusi dan konsekuensial. Metode atribusi dam konsekuensial telah banyak di implementasikan pada pengukuran carbon di Eropa dan Amerika. Sumber emisi karbon diklasifikasikan berdasarkan kategori aktivitas konsumsi dan produksi. Namun di Indonesia, kebakaran hutan dan lahan merupakan sumber emisi karbon tertinggi yang dihadapi hampir setiap tahun pada musim kemarau di lahan gambut. Eksploitasi lahan gambut mengakibatkan kebakaran hutan dan penggundulan hutan tropis di Indonesia. Dampak yang ditimbulkan oleh kebakaran adalah hilangnya manfaat ekosistem tanah dan keanekaragaman hayati. Lahan gambut di Indonesia tercatat menghasilkan 68,6 gigaton karbon atau setara dengan 10% hingga 14% sumber karbon organik dunia. Pengukuran dan pelaporan jejak karbon akibat kebakaran hutan dan lahan dapat menggunakan metode akuntansi. Penelitian ini menggunakan telaah sistematik literatur. Literatur yang digunakan berasal ahli akuntansi karbon dari inggris yang terpublikasi pada jurnal terindeks scopus. Hasil penelitian menunjukan bahwa metode atribusi dan konsekuensial dapat digunakan sebagai salah satu pendekatan untuk mengukur jejak karbon akibat eksploitasi lahan gambut. Pemerintah Indonesia dapat mengadaptasi metode ini dalam membangun akuntansi sirkular dari pengukuran dan pelaporan emisi karbon.

Kata kunci: Akuntansi Karbon, Consequential Methods, Attributional Methods.

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1. Introduction

One of the threats facing humans and the environment is climate change, which occurs over a very long period. One widely implemented response to this threat is to develop methods and practices in information, understanding, interpreting, and measuring the impact of greenhouse gases and carbon emissions. For example, practice methods that have been implemented in several countries such as the United Kingdom, and the United States includenational greenhouse gas inventories (Miettinen et al., 2017; Di Vaio et al., 2023), community or city-level inventories (British Standards Institute 2013; GHG Protocol, 2014), corporate level inventories (WBCSD/WRI 2004; ISO, 2006c), product-level life cycle assessment (British Standards intituies 2008; ISO, 2013c), project level assessments (WBCSD/WRI 2005; ISO, 2006b), and policy-level assessments (WRI 2014c) (Brander, 2016; Brander et al., 2018). Businesses, governments, non-governmental organisations, and other organisations measure and report data on carbon and greenhouse gas emissions using this legislation as a guide.

Attention to weather changes due to global warming is no longer only a concern for natural science disciplines. However, it has also spread to social sciences because of human behavior as a cause of natural damage. Several countries, such as the United States, Canada, Australia, Japan, the United Kingdom, and even Bangladesh, have proven that investors are very concerned about the role of companies in overcoming this global warming issue (Patrianti et al., 2020). Numerous international organisations have created methods for accounting for emissions of greenhouse gases and carbon dioxide. This category of accounting methods consists of attributional methods and accounting methods with a consequential approach. Many nations frequently employ both methods to calculate their accounting-based emissions of carbon and other greenhouse gases (Brander, 2016).

Research on developing accounting techniques for assessing carbon and greenhouse gas emissions is remarkable. First, the grave threat posed by climate change makes inquiries about what regulations and processes are in effect to control carbon and other greenhouse gas emissions. Several measurement techniques were created using semi-isolated approaches, and concerns about differences and parallels between conceptual frameworks emerged. This situation creates opportunities for various sciences and innovations in measurement standards that have not yet been developed in these areas. Carbon measurements that have been used are attributional and consequential methods. The attribution method provides an approach to measuring carbon emissions as a stock, while the consequential method aims to estimate changes in total emissions caused by human activities (Brander et al., 2018).

Environmental quality has become a much-debated issue in the past decade (Hawari et al., 2024). Carbon emissions and greenhouse gases are important issues related to the economy and global warming (Hawari et al., 2024; Akhtar et al., 2021). This emission threat is classified as a transitional threat and affects the development of economic costs. Central and local governments must consider future environmental costs (Hawari et al., 2024; Rasebechele et al., 2024).

Numerous countries have systematically measured their carbon footprints to reduce the environmental impact of their emissions. Carbon emissions are generated mainly by human activities related to production, distribution, and consumption (Tukker et al., 2020). Rapidly increasing carbon emissions encourage the implementation of carbon accounting. Countries in Europe, America, and Asia are working to develop accounting standards to increase accountability and transparency for the industry (Tukker et al., 2020). According to the value chain, which includes production-based, consumption-based, extraction-based, income-based, value-added-based, and combined (mixes of the above) (Taschini, 2021; Brander & Bjørn, 2023), responsibility for reducing emissions and carbon sources can be distributed.

Measurement of carbon footprint and environmental impact is closely related to carbon accounting. Carbon accounting is an accounting approach specifically designed to identify, measure, report, and manage greenhouse gas emissions (GHG) produced by an organization (Somers et al., 2023; Miller et al., 2022). The main goal of carbon accounting is to understand and manage the impact of companies on climate change. Implementing carbon accounting will assist entities in taking concrete steps to manage and mitigate operational impacts on climate change, in line with efforts to achieve environmental sustainability (Brander, 2022).

However, Indonesia does not yet have specific accounting standards that regulate carbon measurement, reporting, and management. Indonesia only has special regulations in improving environmental quality, namely Law Number 32 of 2009 concerning the environment (Tjoanto & Tambunan, 2022). Some global initiatives, such as the GHG Protocol, can be a standard reference for companies that want to engage in carbon emissions measurement and reporting. The GHG Protocol provides guidance for identifying, measuring, and reporting greenhouse gas emissions, and many international companies adopt these principles in sustainability reports (Wiprächtiger et al., 2023). Therefore, academic information is needed about carbon measurement techniques and forms of accountability for carbon produced.

An approach for measuring carbon emissions that can be applied is the attributional and consequential methods. Matthew Brander, a carbon accounting expert at the University of Edinburgh, created the technique in 2016. Both approaches include complete features for calculating carbon emissions and their effects on the environment. Carbon emissions that are explicitly linked to certain activities or entities will be taken consideration using the attributional method (Brander, 2022).

This method is useful for measuring and reporting direct emissions from electricity, production, transportation, and fosil fuels. Meanwhile, the consequential method in carbon accounting standards will consider the broader impact of carbon emissions, including their effects on climate change, environmental, social, and economic (Brander, 2016). This method will analyze the environmental impact of the entire supply chain or product life cycle.

Forest and/or land fires (KARHUTLA) are situations where forest and/or land fires occur, which can cause economic losses and environmental damage. Handling forest

and/or land fires is carried out as an effort to save living creatures affected by forest and/or land fires. The occurrence of peatland and forest fires has an impact on human health such as respiratory tract infections, eye pain and coughs due to forest fires. Apart from that, fires also have an impact on the surrounding environment, such as damage to air quality, so that the air becomes less suitable for drinking. In an attempt to save living things impacted by forest and/or land fires, handling these types of flames is done. The occurrence of peatland and forest fires impacts human health, such as respiratory tract infections, eye pain, and coughs, due to forest fires. Fires also impact the surrounding environment, such as damage to air quality, making the air less suitable for drinking. This incident also affects socio-economic aspects, causing the loss of livelihoods of people who still depend on forests (farming, livestock, hunting/fishing), decreased wood production, disruption of transportation activities, protests and demands from neighboring countries due to the impact of fire smoke, and increased expenditures due to costs for extinguishing (Miettinen et al., 2017).

Indonesia has 13.4 million hectares of tropical peatland area. Peatlands are ecosystems that are sensitive to climate change. Especially with the irreversible drying nature of peat, it will be difficult to wet it again (Omar et al., 2022). Indonesia's tropical peatlands produce 68.6 gigatons of carbon, representing 10% to 14% of the world's organic carbon sources. The carbon is generated from forest fires and tropical deforestation. For example, in 2015, forest fires engulfed 2.6 million hectares of peatland in Sumatra and Kalimantan. These fires produced 1.23 gigatons of carbon. Measuring the carbon footprint of forest and land fires is critical. The carbon measurement method would be important to understand the land fire impact and develop effective mitigation strategies. Due to forest and land fire activities in Indonesia, several methods are needed to determine the carbon footprint measurement. The carbon footprint will be measured using attributional and consequential methods from an accounting perspective.

Carbon and greenhouse gas emission accounting methods have been developed by several world organizations. This category of accounting methods is divided into two groups, namely accounting methods with consequential methods and attributional methods. Many countries often use both of these approaches to measure carbon and greenhouse gas emissions from an accounting perspective. The development of accounting methods for measuring carbon and greenhouse gas emissions is an interesting topic in research. First, the dangerous threat of climate change raises questions about appropriate methods and practices for managing carbon and greenhouse gas emissions. Second, many measurement methods are developed from the side of semi-isolated practices, and the emergence of questions about similarities and differences between conceptual frameworks. This study is a replication of the research results of Matthew Cuchulain Brander, a professor of carbon accounting from Edinburgh Business School. Four research results were reviewed as a step in forming a carbon measurement method.

2. Research Method

The research method used in this research is a literature review. Literature review systematically examines and evaluates existing literature on a particular research topic or problem. This study used four articles as main sources and ideas. The articles wrote by Professor Matthew Brander from Edinburgh Business School. He is an expert on carbon accounting measurement. The method involves assessing a product's or process's environmental impact at a specific time, without considering the consequences of changes in production or consumption (Brander & Bjørn, 2023). The method would analyse and measure the direct impacts of carbon effect, such as CO2 emissions from the production process, raw materials, energy use, and waste. The method suits steady-state environmental impact assessment to compare existing products or processes. On the other hand, the methods were more holistic because they take a dynamic approach that considers the consequences of changes in the system resulting from the use of a product or process (Brander, 2016). This means that in addition to the direct impact of a product or process, consider the indirect impacts and system changes caused by additional or reduced consumption or production. This approach helps evaluate the impact of behaviour, technology, or policy changes. The analysis's objective and the system's intricacy for consideration will determine which of these approaches is appropriate. This reference is used in consequential and attributional techniques of measuring carbon.

3. Results and Discussion

3.1. Results

Carbon measurement using attributional and consequential methods has been widely used in European carbon accounting theory (Brander et al., 2021). These two methods were chosen for carbon management, with the inventory method having a broad impact on the industry and supporting government policy (Brander & Bjørn, 2023). It is important to explore carbon stocks in decision-making. Attribution focuses more on direct and indirect emissions related to an entity's operations, while consequential considers the long-term impact of operating activities on the system as a whole. Appendix 1 shows the carbon and greenhouse gas accounting standards for measuring and reporting from a consequential and attributional perspective.

Four categories of emission sources are classified based on attributional and consequential methods. Table 1 shows these categories of emission sources.

Table 1. Classification of Emission Sources

Categories	emission sources
Group 1	natural gas, diesel, biodiesel, fuels
Group 2	electric power plant
Group 3	sales of goods and services, fuel and energy, waste from production activities, transportation
Group 4	biodiesel fuel, wood biomass

Sumber: (Brander, 2016)

Attributional and consequential methods classify carbon emission sources in two main categories based on approaches to carbon measurement and reporting. Table 2 shows the classification of emission sources.

Table 2. Classification of Emission Sources

Attributional	*Consequential*
Direct Emissions Emissions from sources directly related to the operation or activities of the entity. a. Burning fossil fuels in the production process. b. Emissions from vehicles and operational equipment. c. Emissions from industrial or production processes.	Direct Emissions Carbon emissions that are directly caused by the industry's operations and activities. These are classified similarly to how attributional methodologies are used.
Indirect Emissions Emissions connected to an entity's energy or raw material use, but not directly produced by the entity's operations, include. a. Emissions from power plants that supply energy to entities. b. Emissions from the distribution and transportation of goods used by the entity. c. emissions resulting from the manufacturing of products or services that a company purchases.	Induced Emissions Emissions arise as a direct result of the impact of an entity's activities or products on an economic or environmental system. a. Changes in consumption or production patterns in response to the activities of the entity. b. Changes in transportation patterns or energy use more broadly as a result of an entity's operations.
	Displacement Emissions Emissions that occur when an entity's activities replace or shift other, more environmentally friendly activities include: a. Emissions reduction from the use of renewable energy or clean technologies as a result of the entity's investment or activities. b. Changes in the supply or demand of energy in the market result from the entity's activities.

Source: (Brander, 2016)

Carbon measurement methods using attributional and consequential approaches have unique advantages. Entities using these two methods to reduce carbon emissions should consider these advantages. Table 3 shows the advantages of attribution and consequential methods.

Both methods have value and relevance in the context of carbon accounting, and the decision to use one or a combination of the two. It is tailored to the specific goals and needs of the entity or organization. Sometimes, combining these two methods can provide a complete and more accurate picture of an entity's carbon footprint. However, this method also has drawbacks that must be considered when implementing it. Table 4 shows the disadvantages of attributional and consequential methods.

Table 3. Advantages of Attributional and Consequential Methods

Method	Advantage	Explanation
Attributional	Simple and easy to implement	Attributional methods tend to be more direct and simpler. This makes it easy to implement in carbon accounting practices, especially for companies or organizations that are just getting started measuring and reporting carbon emissions.
	Direct emission measurement	This method is suitable for measuring direct carbon emissions from specific operations or activities. Understanding the direct impact of an entity's activities on the environment is helpful.
	Easy to monitor and track	Focusing on direct emissions at specific points in time makes this method easier to monitor and track, which ensures consistency in carbon emissions reporting.
Consequential	provide a holistic understanding	The consequential approach provides a more holistic understanding of the full impact of an activity or product. This includes the domino effect and the long-term effects of decisions, allowing the entity to see the impact thoroughly.
	Anticipating secondary impacts	This method allows for anticipating and measuring the secondary or indirect impact of certain activities, such as changes in consumption patterns or changes in supply chains. This helps in understanding the possible indirect impact on the environment.
	More accurate in strategic planning	Consequential methods can help in strategic planning and better decision-making regarding carbon management and climate change mitigation by considering the long-term consequences of an activity or product.

Source: (Brander, 2016)

Table 4. Disadvantages of Attributional and Consequential Methods

Method	Disadvantages	Explanation
Attributional	Inaccurate Calculations	tend to ignore the domino or side effects of a decision or action. This can result in inaccurate calculations because it does not consider the overall impact of an activity.
	Limitations in Planning	An attributional approach might incentivise entities to fix only certain aspects of operational activities directly responsible for carbon emissions, without considering the overall environmental impact.
Consequential	Calculation Complexity	A very complex method of determining the overall impact of a decision or action. The calculation of this method is complicated and requires extensive data to estimate the domino effect of an activity.
	Limitations of Information	The insufficient quantity of information available frequently affects its application, particularly when determining an action's or a decision's long-term effects.
	Cost and time	This method requires significant resources to collect data and perform the necessary analysis.

Source: (Brander, 2016)

Researchers often use combined methods to overcome these weaknesses to adjust to carbon measurements' specific goals and needs (Brander & Bjørn, 2023; Brander

et al., 2021). In addition, researchers and institutions related to climate change continue to encourage research and development in carbon measurement methods, which can help overcome some existing weaknesses and improve the accuracy and relevance of the results. Through attributional and consequential methods, entities can provide more comprehensive carbon reports. These reports include a good understanding of current emissions and proper planning to reduce future carbon impacts. This allows stakeholders to get a more complete picture of the entity's contribution to climate change and the efforts made to reduce the entity's carbon footprint.

3.2. Discussion

The Important Role of Accounting in Carbon Reduction Action

Carbon reduction actions were beyond compliance with regulatory and reporting requirements; it is also about risk management, operational efficiency, and social and environmental responsibility. From an accounting perspective, entities measure, report, and manage carbon impacts; however, this would affect in financial conditions. The expert on carbon accounting created the movement to reduce the carbon effect, which is shown in Table 5.

Table 5. Carbon Reduction Action from an Accounting Perspective

Type (Base)	Target Group	Carbon Reduction Action
Production	Manufacturer	Action to reduce emissions and their sources using fields or plants, such as government support by implementing policies with environmentally friendly technology standards.
Consumption	End consumer	Spending on low-impact goods and services should be distributed (among product categories or category groupings) to support policies such as environmental taxes, sustainable procurement laws, and eco-friendly product packaging.
Income	Seller; producer or processor	Designing products and services with little environmental impact, such as eco-design and sustainable production schemes.
Value added based	All actors in a value chain	Find those parties that can implement reductions in greenhouse gas emissions and carbon emissions, as these actors will have an economic influence on the value chain. The theory of a carbon value-added tax can support this kind of policy. However, its practical implementation will be tricky due to several constraints on the goods and services supply chain.

Source: (Tukker et al., 2020)

Implementing such policies may require rigorous monitoring and reporting using relevant accounting principles, especially those focusing on sustainability and sustainable practices. Entities can significantly contribute to climate change mitigation efforts, especially in reducing carbon emissions.

The Important Role of Carbon Accounting in the Circular Economy

Carbon accounting is essential for helping entities achieve sustainability goals in a circular economy by providing tools to measure and manage the environmental impact of an entity's economic activities and report carbon emissions transparently. A circular economy is designed to reduce resource wastage, optimize material use, and minimize environmental impact. In a circular economy, resources are retained, recycled, and reutilized as efficiently as possible. The circular economy aims to achieve sustainable development by minimizing negative environmental impacts, reducing waste, and improving resource usage efficiency. This approach is increasingly important due to global awareness of environmental and sustainability issues. The circular economy is important in reducing carbon emissions and mitigating the greenhouse effect. Using appropriate accounting principles and practices, companies can better contribute to circular economy goals, minimize environmental impact, and improve resource use efficiency. The aim is to reduce the impact of emissions resulting from a company's business activities.

4. Conclusion

The carbon footprint should be measured using attributional and consequential methods from an accounting perspective. This makes implementing carbon accounting practices easy, especially for companies or organisations that measure and report carbon emissions. Direct emission measurement. This method is suitable for measuring direct carbon emissions from certain operations or activities. It is simple to monitoring and tracking carbon effect, as the focus is on direct emissions at a specific time, which is important for ensuring consistency in carbon emissions reporting. This method makes it possible to anticipate and measure secondary or indirect impacts of certain activities, such as consumption patterns or supply chain changes. More accurate in strategic planning by considering the long-term consequences of activities or products, the Consequential method can help in strategic planning and better decision-making related to carbon management and climate change mitigation.

Both methods have value and relevance in the context of carbon accounting, and the decision to use one or a combination of the two has limitations in Planning. The attributional approach may incentivise entities to improve certain aspects of operational activities directly responsible for carbon emissions without considering the overall environmental impact. Consequential has a comprehensive method for calculating the overall effect of a carbon emission reduction decision or action. This method's calculations are complicated and require extensive data to estimate an activity's domino effect. By combining attributional and consequential methods, entities can provide more comprehensive carbon reports that include a good understanding of current emissions and appropriate planning to reduce future carbon impacts. This allows stakeholders to get a more complete picture of the entity's contribution to climate change and the efforts to reduce the carbon footprint resulting from the entity's operational activities. The circular economy aims to achieve sustainable development by minimising environmental negative impacts, reducing waste, and increasing resource use efficiency. Using appropriate accounting principles and practices,

companies can better contribute to circular economy goals, minimise environmental impacts, and increase resource efficiency.

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Appendix 1. Categories: Carbon and Greenhouse Gas Accounting Methods

Action	Standard
	Consequential Method
Product (Consequential LCA)	1. International Reference Life Cycle Data System Handbook (European Commission, 2010). 2. Guidelines for applying deepened and broadened LCA (Weidema, 2009). 3. Market Information in life cycle assessment (weidema, 2003).
Project	1. Clean Development Mechanism Methodologies (UNFCCC, 2014). 2. Verified Carbon Standard Methodologies (Verified Carbon Standard, 2014). 3. Greenhouse Gas (GHG) Protocol for Project Accounting (WBCSD/WRI, 2005). 4. ISO 14064-2:2006 (ISO, 2006d).
Policy	1. Greenhouse Gas Protocol: Policy and Action Standard-Final Draft (WBCSD/WRI, 2014a).
	Attributional Method
Product (Attributional LCA)	1. ISO/TS 14067:2013 (ISO, 2013b). 2. Product Environmental Footprint (European Commission, 2013). 3. PAS 2050:2011 Specification for assessing goods and services' life cycle greenhouse gas emissions (British Standards Institute, 2011). 4. International Reference Life Cycle Data System Handbook (European Commission, 2010). 5. Greenhouse Gas Protocol: Product Life Cycle Accounting and Reporting Standard (WBCSD/WRI, 2011c). 6. ISO 14040:2006 (ISO, 2006a). 7. ISO 14044:2006 (ISO, 2006b).
Community	1. Global Protocol for community-scale greenhouse gas emissions (GPC). 2. PAS 2070: 2013 Specification for the assessment of greenhouse gas emission of a city (British Standards Institute, 2013). 3. U.S Community protocol for accounting and reporting of greenhouse gas emission- version 1.1 (ICLEI, 2013).
National	1. IPCC guidelines for national greenhouse gas inventories 2006 (IPCC, 2006).

Source: (Brander, 2016)