Exploration of establishing a unified carbon accounting method in the field of public buildings

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Abstract. Under the background of low-carbon development, the construction of green public buildings is an inescapable responsibility and mission. At present, there are relatively few studies on carbon emission of public buildings in China and there is a lack of unified and standardized carbon accounting methods. Therefore, based on the domestic research status, this paper reviews the research progress and trend of carbon emission in public buildings. Sorting out the common accounting boundaries and accounting scope in the field of public buildings; By constructing the interactive accounting method framework of public buildings, the process and method of carbon accounting are sorted out. Various points for attention in the process of accounting are clarified from data acquisition, data management, accounting analysis and other aspects. This study provides a theoretical framework for carbon accounting in the field of public buildings and lays a foundation for establishing a unified carbon emission accounting method system in the field of green public buildings.

1 Introduction

Climate warming is considered to be one of the major problems jeopardizing the survival and development of human beings in the future, With atmospheric carbon dioxide levels continuing to rise (from 0.315‰ in 1958 to 0.415‰ in 2021 [1]), carbon dioxide emissions already account for 73% of total greenhouse gas emissions [2], and reducing carbon dioxide emissions has become a consensus of the international community. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the global average temperature has increased twice as fast over the past 50 years as it did over the past 100 years [3].The International Energy Agency's Carbon Dioxide Emissions 2022 [4] shows that China is the world's largest carbon emitter and plays a key role in global climate governance. Among them, the construction sector is one of the main areas contributing to elevated greenhouse gas emissions [5]. Through the statistics of recent years, it can be concluded that the GHG emissions from the construction sector are second only to coal, electricity, industry, transportation and other high-energy-consuming sectors [6-8].In the 21st century, with the gradual emergence of low-carbon concepts, green buildings and zero-carbon buildings [9-12] have gradually appeared in people's vision, and the energy-saving standard has also gradually increased from 30% energy-saving rate in 1986 to 65% [13].In September 2020, the Chinese government explicitly proposed to realize the "Carbon Peak" in 2030 and "Carbon Neutral" in 2060, and issued the relevant action plan in 2021, which further accelerated the pace of the development of low-carbon buildings in China, In September 2020, the Chinese government clearly put forward the low-carbon goal of achieving "carbon peak" by 2030 and "carbon neutrality" by 2060, and issued the relevant action plan in 2021, which further accelerated the pace of development of low-carbon buildings in China. At present, for a variety of energy-consuming scenarios such as heating [14], cooling [15], and power supply [16] in the field of buildings, a large number of scholars have done relevant research, but the low-carbon research in the field of public buildings is still stuck in the stage of building energy efficiency and energy saving of control [17], and in the field of statistics of greenhouse gases and carbon emission accounting is still in the initial stage, and there is still no unified carbon emission accounting in the field of public buildings. standards.

2 Accounting methods and characteristics

2.1 Methodological framework

This paper proposes an interactive carbon accounting framework for public buildings (Figure 1). The framework takes the establishment of a unified and standardized statistical accounting system for carbon emissions in the field of public buildings as the core objective, and is divided into six links, each of which is optimized through data interaction and information nesting to ensure the correctness of the final accounting data.

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The various components of the interactive carbon accounting framework for public buildings are listed below:

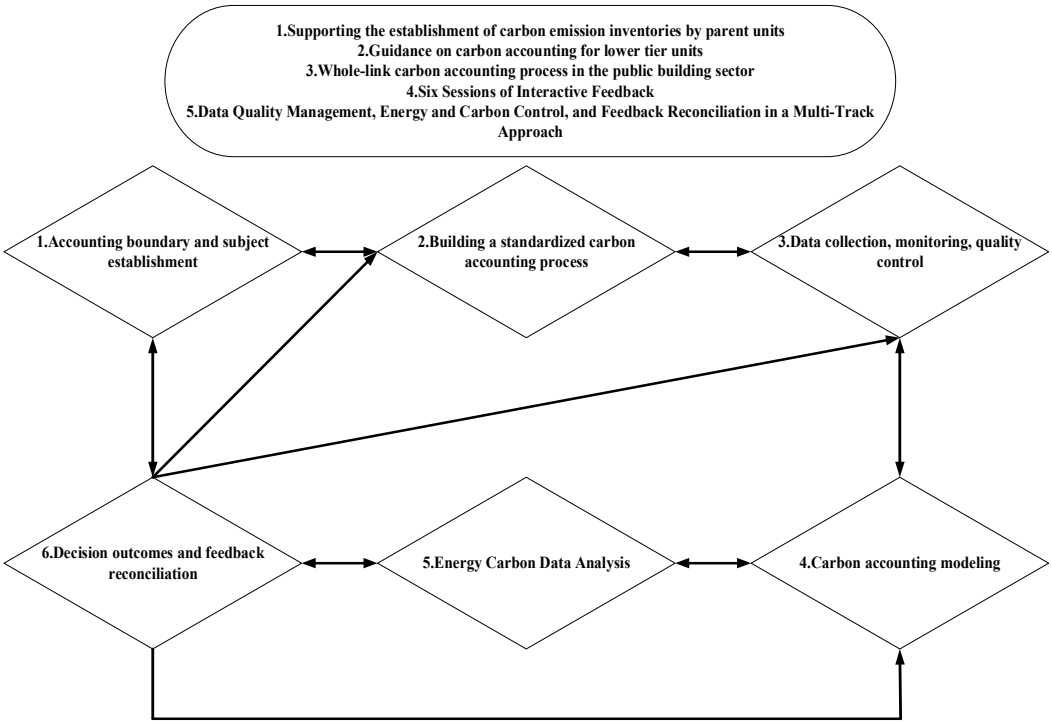

Figure. 1. Interactive carbon accounting framework for public buildings

(1) Accounting boundaries and subjects are established:

For public building scenes that require carbon accounting, clarify the scope of accounting within the scene, determine the main body of accounting and boundaries under the scene, and try to adopt a unified organizational management boundary, carbon accounting boundary, and information statistics collection boundary under the stipulated scene, and at the same time, divide the various boards within the boundary, and make clear the flow of carbon sources between the boards, so as to ensure the accuracy of the accounting data, and to avoid duplication of statistics.

(2) Building a standardized carbon accounting process

Define the energy structure of different application scenarios in the region, make preliminary judgment on the focus of the accounting, build a standardized carbon accounting process, establish an accounting checklist to avoid missing items, omissions, errors, etc., during the accounting process, and strictly control the accounting steps according to the standardized carbon accounting process, so as to ensure the completeness of the accounting results.

(3) Data collection, monitoring, quality control

It mainly focuses on four aspects, namely, data perfection, data authenticity, data typicality and data reasonableness, and should strictly control the data collection and process, do a good job of data quality control, make the data real and reliable, and make improvements according to the results.

(4) Carbon Accounting Modeling

According to the mainstream accounting standards at home and abroad in the field of public institutions and buildings, combined with the actual application scenarios, to build customized carbon accounting model, the international commonly used accounting methods include the emission factor method, the material conservation method, and the online monitoring method. This paper focuses on the emission factor method, which mainly calculates the carbon emission data through the product of activity level data and emission factor, and according to the actual situation of application scenarios, it can be supplemented with online monitoring method to obtain carbon emission data.

(5) Energy Carbon Data Analysis

Based on the results of energy data accounting, data quality check conclusions, energy and carbon data analysis, judging the accounting scenarios in the field of public buildings carbon emissions level, can be developed energy-saving points for the construction of the upper unit of the carbon emissions inventory to provide data support for the lower unit to carry out carbon accounting for the analysis of the guidance to build the foundation for the construction of the public buildings in the field of carbon verification of a network.

(6) Decision-making results and feedback regulation

According to the data monitoring situation, quality check reliability, carbon accounting authenticity, actual energy consumption, presenting the complete public building energy and carbon situation with full coverage of energy within the accounting boundary, deriving the decision-making results, identifying the key emission points, high energy consumption points, energy saving and carbon reduction points of public buildings, supporting the rationalization of public buildings to reduce carbon at the same time as feedback adjustment of the overall accounting process and iterative optimization of defective parts.

2.2 Boundary division of accounting for public buildings

This paper mainly divides the carbon accounting of public buildings into four major boundaries: construction boundary, operation boundary, management boundary and energy flow boundary [18]. The four major boundaries have different management scopes and different functions, but the application scenarios have the same scope, differentiated and homogeneous, interacting and feeding back to each other in the carbon accounting management process to avoid verification errors. In the process of boundary delineation, it is crucial to delineate a reasonable boundary, which is the first and most critical step for accurate carbon verification of public buildings. Accounting boundary delineation, not only need to require that the various boundaries have a uniform caliber, but also require that the boundary delineation process combined with the real situation, with practical significance, so that the accounting results have a boundary effect, and can play a supportive and guiding role for the upper and lower levels of the unit. As show in table 1.

Table. 1. Connotation and characteristics of the four major borders

name	Connotation and Characteristics
Construction of boundaries	Relevant information can be obtained in the management of the construction materials related to the higher level of government, the main explosion of civil building construction, production building construction, infrastructure construction and so on.
Operational boundaries	It mainly includes carbon emissions generated during the operation phase of buildings, such as energy consumption of public buildings in towns and villages and heating energy consumption in the north.
Managing boundaries	Mainly refers to the boundary between the user and the territorial district in which it is located, which involves the operation of carbon emission organizations and the division of responsibilities.
Energy Flow Boundaries	System boundaries for process analysis of material, energy, and carbon flows within a scenario.

2.3 Scope of accounting for public buildings

In order to avoid double accounting of the same energy data in the process of participating in upstream and downstream accounting, at present, in the larger scope of carbon accounting, the international community has already had a unified standard for the division of carbon emissions(Figure 2), and in the greenhouse gas accounting system compiled by the World Resources Institute and the World Business Council for Sustainable Development for enterprises/organizations, carbon emissions are divided into the scope of the first, second, and third [19,20], which were subsequently widely used.

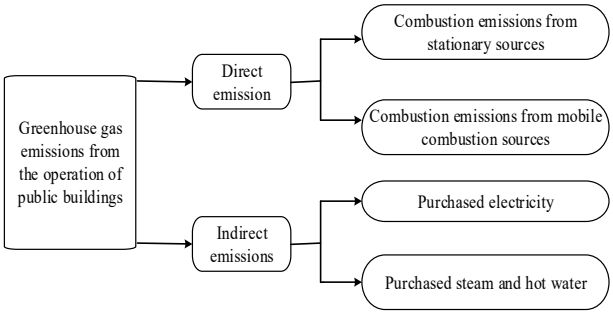

Figure. 2. Scoping of carbon accounting

This emission scope division method is applicable to all levels of application scenarios, and in the process of practice, it should adhere to the principles of grasping the big and letting go of the small, the first easy to be followed by the difficult, and the gradual progression of the layers, combining with the actual scenarios of carbon emissions, the accounting objectives, and the participant population, and ultimately determining the scope boundaries of the need to be accounted for, and clarifying the scope division of the various sources of emissions, by means of the interaction and regulation of the various accounting links [21].

3 Accounting data management and analysis

3.1 Data acquisition

This carbon verification study mainly focuses on the emission factor method, relying on mainstream accounting standards, such as, 24 Guidelines for Accounting Methods and Reporting of Greenhouse Gas Emissions in Industries (for Trial Implementation) issued by the General Office of the National Development and Reform Commission of China, the Standard for Calculating Carbon Emissions from Buildings issued by the Ministry of Housing and Urban-Rural Development, and the Guidelines for Accounting and Reporting of Greenhouse Gas Emissions from Enterprises for Power Generation Facilities issued by the Ministry of Ecology and Environment, According to the actual application scenarios, it is possible to Assisted by online monitoring method, the emission factor method is mainly calculated by activity level data in the process of practical application, but according to different application scenarios, the acquisition of energy data is often constrained by the on-site environment, collection equipment, data confidentiality and other factors, resulting in the acquisition of data is limited or incomplete, in which case it is necessary to supplement the data processing by other methods, The main sources of carbon emissions are divided as shown in Table 2. According to the different ways of data processing, the priority of the data available are also different (Table 3), in the process of data capture should be based on the standard, the reliability of the data to do a detailed note, according to the order of priority, select the more reliable data, to ensure the accuracy of the accounting results.

Table 2 Classification of major sources of carbon emissions.

Form	Clarification
Combustion emissions from stationary combustion sources	Emissions from the combustion of fossil fuels in stationary combustion sources, e.g., boilers, stoves, dryers, etc.
Combustion emissions from mobile combustion sources	Transportation, etc.
Emissions from fugitive sources	Refrigerators, air conditioners, fire extinguishers, septic tanks, etc. (fugitive generation of small emissions).
Emission offsets for newly planted trees	Tree planting offsets vary by building type, and public building scenarios vary widely and need to be tallied according to the actual situation.
Emissions from purchased electricity and heat	Although used by the emitting unit, electricity and heat are production units and are indirect emissions.
Emissions from commissioned transportation	Commissioning a third party to undertake emissions from transportation is more complex to count and care needs to be taken to avoid double counting.

Table 3 Main sources of data and prioritization

Priority	Accounting data sources
High	Data from direct monitoring such as: system monitoring data, hardware equipment acquisition data, invoice, ledger, billing records
Medium	data, etc. Tested converted data: 1. Converted values of statistical data from statistical agencies/yearbooks/evaluation reports, etc., e.g., national statistical yearbooks. 2. Empirical data or standardized values provided by relevant standards/guidelines/manuals, such as guidelines for the preparation of provincial GHG inventories, etc. 3. Data from literature/databases, e.g., IPCC emission factor database. 4. Empirical data from industry/enterprise expert studies.
Low	1. Standardized formula data 2. Proxy data from approximate activities

3.2 Data quality management

In order to ensure the accuracy of the data, the usefulness of the accounting results and the supportability of the upper and lower modules. Quality checks must be carried out on the acquired data before the accounting is carried out to ensure that the original erroneous data are corrected in a timely manner. The process of data checking is mainly judged by four aspects, namely, data perfection, data authenticity, data typicality and data reasonableness (Figure 3), and a complete test document is left in the judgment process so that improvements can be made according to the test results.

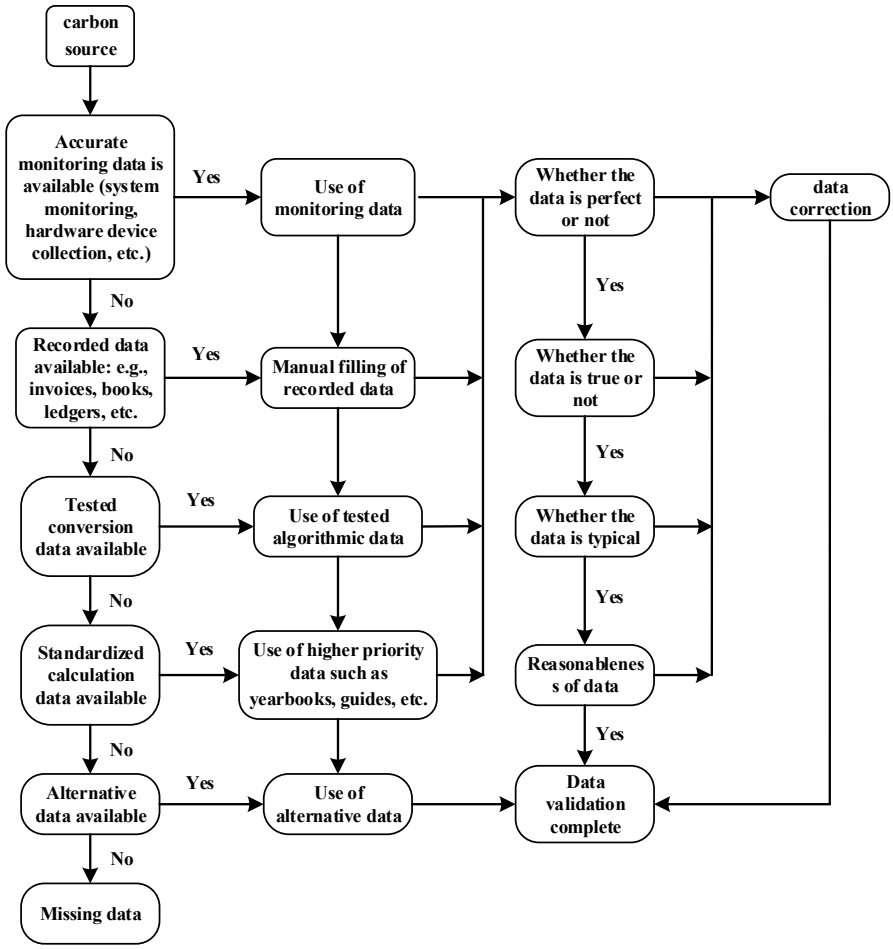

Figure 3 Block diagram of the carbon accounting data quality management process

The authenticity of the source of data mainly refers to sorting out, checking and judging the means of obtaining data and the source of data. Ensure that the data come from the most reliable data within the available range.

Typicality of data mainly refers to whether the acquired data are time-sensitive, typical and timely, whether the selection is in line with the basic characteristics of the region, whether it is the most representative data in the region, whether the latest technical means are used in data collection and acquisition, whether the application scenarios match with the technical means used, and whether the acquired data are generalizable.

The reasonableness of the data is mainly to check the upper and lower carbon accounting units to see if there is any double-counting, such as the cumulative data of the lower unit exceeding that of the upper unit, double-counting of carbon emission data among the lower units, and omission of carbon emission data in the upper unit.

3.3 Accounting analysis

Carbon accounting is a necessary step for converting energy data into carbon data in different application scenarios, and its main kernel is based on the emission factor method, through the interactive carbon accounting framework for public buildings, and the carbon emission results are calculated based on a variety of energy factor coefficients, which are very different in different application scenarios and different types of energy, so we can refer to the more popular unified greenhouse gas emission official guidelines that have already been released. Therefore, we can refer to the popular unified GHG emission accounting methodology guidelines that have been released by the government, such as China's 24 industry GHG accounting methodology guidelines, provincial GHG inventory compilation guidelines, reporting guidelines, ISO14064 [22], ISO14067[23], GHG emission accounting methodology for industrial enterprises, and the IPCC National GHG Inventory Guidelines [24]. As the actual application of different scenarios varies greatly, the following points need to be noted in the accounting process:

(1) Carbon accounting not only focuses on the results, but also the methodology, data, scope and scenarios of the accounting process, which should also be "up and down compatible", so as to be able to not only support higher-level carbon verification, but also guide the planning of low-carbon pathways for bottom units, and to have practical application significance.

(2) In the carbon accounting process, it is important to clarify the distinction between energy consumption, energy for fuels and energy for raw materials.

(3) For cases where upstream and downstream links are located outside the calculation scenarios, there may be problems such as difficulties in data collection and double-counting of accounting data when carrying out carbon accounting for upstream and downstream units, which should be challenged on a case-by-case basis to avoid double-counting of energy data between scopes I, II and III.

(4) For the calculation of natural carbon sinks, most of the existing accounting guidelines, in order to reduce the workload, directly give the amount of carbon sequestered per unit area of green space based on global or regional averages, but there is no differentiated analysis of the growing environment of the plants, the plant species, and the management methods, and there is a large degree of uncertainty.

(5) In some application scenarios, carbon emission reduction data realized through energy efficiency improvement, green power purchase and other means should be clearly attributed to the scope in the actual carbon accounting process, and those that have been embodied in the calculation of actual carbon emissions should not be deducted repeatedly as emission reduction.

4 Summary

Carbon accounting and monitoring in different application scenarios should insist on seeking common ground while reserving differences, with the core objective of constructing a unified standardized carbon emission statistical accounting system, strictly implementing the six links of carbon accounting, and following the framework of interactive carbon accounting methods for public buildings. Between the six links each other feedback support, iterative optimization, interaction, according to the specific application scenarios of public buildings, in the use of the process of continuous search for excellence, continuous improvement and updating, so as to build a standardized and unified and distinctive carbon accounting methodology system.

Carbon emission calculations in accordance with the public establishment of an interactive carbon accounting framework can realize the compatibility of the calculation results with the accounting data of the upper and lower levels of units, which can not only provide support for the higher-level units, but also provide low-carbon guidance to the lower-level units, which will help to promote the rapid development of China's "dual-carbon" construction.

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