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Development and implementation of carbon accounting models and standardization platforms in public institutions

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Abstract

Public institutions, emblematic of public infrastructure, exhibit extensive reach and operational scope, positioning them as vanguards in China's dual carbon initiatives and serving as exemplars. Electricity and natural gas predominantly fuel the operations of public institutions. Notably, the fixed commute routes and consistent procurement patterns of office personnel yield a standardized energy consumption profile within these entities. Researching carbon emissions related to commuting and evaluating procurement strategies for reducing carbon footprints in public institutions demonstrate a precision-tailored approach. This paper, through an analysis of the energy consumption characteristics, utilization structure of public institutions, and the commuting behaviors and procurement practices of office personnel, establishes a bespoke carbon accounting model specifically designed for public institutions, seamlessly embedded within a comprehensive platform. By providing fundamental methodological frameworks and advanced technological foundations for carbon accounting in public institutions across China, this work propels the nation's efforts towards carbon peak and ultimately carbon neutrality.

Keywords: Public Institutions, Carbon accounting, Standardization, Platform

Introduction

The emissions of carbon dioxide and other greenhouse gases have led to global warming, rising sea levels, and increased frequency of natural disasters. These phenomena not only jeopardize the balance of ecosystems but also significantly impact our production and daily lives, posing a threat to human survival. It has become a pressing global issue that countries worldwide are earnestly addressing, emphasizing the urgent necessity of reducing carbon dioxide and other greenhouse gas emissions to alleviate these challenges. The concept of "dual carbon" has emerged as a pivotal theme in the new developmental phase globally. China's "dual carbon" strategy has already extended into various sectors such as industry, transportation, and construction. Public institutions, emblematic of public infrastructure, play a significant role in China's "dual carbon" initiatives, serving as key elements that lead by example in this critical era.

Public institutions refer to national agencies, public service units, and group organizations that utilize public funds, including government agencies, public service units, hospitals, schools, as well as cultural, sports, and technological facilities. In 2020, there were approximately 1.586 million public institutions nationwide, employing around 500 million individuals, with a total energy consumption of 164 million tons of standard coal, accounting for roughly 3.29% of the total energy consumption in society. The total water consumption of these institutions was 10.697 billion cubic meters, amounting to about 12.39% of the total domestic water consumption in society. As crucial entities in the realm of energy conservation and emission reduction across society, public institutions urgently need to engage in carbon accounting and carbon reduction calculations. While research on carbon accounting for the direct carbon emissions and indirect carbon emissions from the purchase of electricity and heat by public institutions is relatively mature, studies on the carbon emissions from the travel activities of personnel associated with public institutions are scarce. Evaluation of the carbon reduction potential of green travel and green products remains a field that has yet to be extensively explored.

In the realm of accounting for carbon emissions from personnel travel, current research on carbon emissions is limited to certain regions. Challenges such as difficulties in acquiring travel data, low data quality, and measurement inaccuracies have hindered the development of a standardized methodology for calculating carbon emissions associated with various modes of transportation in different regions. This has resulted in a lack of consistency in carbon emission accounting methods. When it comes to evaluating the reduction of carbon emissions from the procurement of office energy-using products, current studies primarily focus on examining the carbon footprints of appliances and similar energy-consuming products. However, assessments regarding the carbon reduction potential of products with varying energy efficiency grades during their usage stages remain relatively unexplored. Regarding energy consumption monitoring platforms, existing systems primarily concentrate on data collection, monitoring, and alerting related to energy usage, rather than encompassing comprehensive monitoring and analysis of carbon emissions data, carbon emission alerts, and carbon reduction assessments. This study aims to address these gaps by developing a national standardized approach for carbon emissions accounting and carbon reduction assessment within public institutions. By exploring methods for calculating emission factors related to personnel travel per kilometer and establishing parameters for energy efficiency in green procurement, the goal is to construct a unified framework. This framework will facilitate the development and application of inclusive carbon platforms, providing a standardized and digitalized pathway for public institutions in China to achieve their carbon peak and carbon neutrality targets.

Literature review

Currently, there are three widely used methods for carbon emission accounting worldwide: carbon emission factor method, mass balance method, and measurement method (Li et al. 2022). These three methods have their own advantages based on the characteristics of different industries and application scenarios. In 1996, the IPCC compiled and published the first edition of the "IPCC National Greenhouse Gas Inventories Guidelines", which proposed the carbon emission factor method, the most widely used carbon emission accounting method to date (Yona et al. 2020). This method is highly operable, and countries and industries have accumulated a large amount of carbon emission factor data, providing data support for carbon emission accounting (Chen et al. 2022). In the construction industry, the carbon emission factor method is also widely adopted. Based on the statistical classification of emission sources, the IPCC divides carbon emissions in the construction industry into direct emissions and indirect emissions (IPCC 2019). Direct carbon emissions in buildings refer to the carbon emissions generated by the direct consumption of fossil energy during the operation phase of buildings, mainly occurring in activities such as building cooking, hot water, and decentralized heating (Huang et al. 2024). Indirect emissions are related to the electricity and heat used in buildings, and carbon emissions occur during the production and transmission processes of these energy sources. The use of electricity in buildings, especially the indirect carbon emissions generated during the operation of electricity loads, along with the direct carbon emissions resulting from consumer behavior, are important components of carbon emission accounting in the construction industry. Therefore, accurately accounting for the carbon emissions of these two parts is crucial for understanding and reducing the overall carbon footprint of the construction industry (Liu et al. 2015).

In China and internationally, there exists a substantial research foundation on carbon emissions accounting in the transportation sector. Authoritative bodies such as the IPCC and China's Ministry of Ecology and Environment primarily employ an "top-down" approach based on energy consumption to calculate transportation carbon emissions (Chen et al. 2023). This method entails acquiring the total fuel consumption and corresponding carbon emission factors for various modes of transportation, multiplying them to compute the carbon emissions. This approach is well-suited for macro-level assessments, aiding in the calculation of national and regional carbon emissions. Concurrently, methods for calculating transportation carbon emissions at the city, district, and community levels often utilize a "bottom-up" approach based on travel data (Yan 2018). This method involves obtaining the travel distances for different modes of transportation and their associated carbon emission factors per unit distance, multiplying them to calculate the carbon emissions from travel. This approach is effective for smaller-scale assessments of transportation carbon emissions, directly relating to metrics such as travel distances and traffic volume, providing clear and intuitive data. In the realm of accounting for carbon emissions from office energy-using products, scholars have introduced the concept of benchmark values and baseline scenarios (Jiao et al. 2023). There are four methods for determining benchmark values: based on existing national energy efficiency standards, government-issued documents, industry consensus, or consumer preferences. Establishing benchmark values supports the evaluation of the carbon reduction potential resulting from the use of green and low-carbon energy products.

Internationally, research on carbon emission reduction has been conducted early on, leading to the development of international standards and research outcomes that are widely applied. In the study of carbon emission reduction methods, the primary basis internationally is the Clean Development Mechanism (CDM) methodology, in addition to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories—2019 Revision*, the ISO 14064 series standards, and the *Greenhouse Gas Accounting System: Corporate Accounting and Reporting Standards*. In the realm of research on methods for reducing emissions from transportation activities, most foreign scholars and research institutions primarily focus on calculating carbon emission reductions based on vehicle usage, vehicle manufacturing, and recycling processes. The results indicate that the vehicle usage phase is the main source of emissions generation (Journalist 2007; Li et al. 2016). In order to efficiently curb the growth of carbon emissions, it is imperative to conduct in-depth research on the vehicle usage phase (Mishalani et al. 2014; Onat et al. 2015; Menezes et al. 2017).

In China, research on carbon emission reduction pathways primarily focuses on industries, construction, and transportation sectors. Within the realm of research on carbon reduction strategies in the construction sector, Yu and others have analyzed pathways for reducing carbon emissions in green buildings (Yu et al. 2021). They posit that policies encouraging carbon emission reduction, carbon offsetting technologies, carbon trading mechanisms, and contract energy management can collectively facilitate carbon neutrality in the operational phase of green buildings. Scholars have devised methods to estimate and analyze carbon emissions from urban passenger transportation systems (including automobiles, rail transit, taxis, and buses) (Fan and Lei 2016; Wang et al. 2015), with findings indicating the effectiveness of transitioning from private automobiles to public transportation in reducing emissions in Beijing. In the study of carbon reductions in green transportation practices, Huang and others advocate for the use of average-based methods to calculate the carbon emissions reduction resulting from citizens' subway travel under a carbon-inclusive policy (Huang et al. 2017). Using Guangzhou as a case study, they quantify the carbon emissions reduction from citizens using subways for commuting. Furthermore, Zhang, focusing on Beijing, has calculated the total carbon emission reduction resulting from residents' usage of shared bicycles in the city (Zhang 2021).

In the realm of monitoring platforms, China has vigorously promoted research on building energy efficiency against the broader backdrop of energy conservation initiatives. Research endeavors on building energy consumption monitoring platforms have flourished extensively. Feng and collaborators have designed an embedded system based on RK3288 for this purpose (Feng et al. 2019). Additionally, Lin and others have integrated ISM wireless network technology with 4G network technology to devise a remote data acquisition solution for the collection, conversion, and transmission of thermal calculation data (Lin et al. 2019). Tian has worked towards the development of a suitable energy consumption monitoring and control system, aiming to enhance monitoring efficiency (Tian 2019). Cao, in alignment with the requirements and characteristics of software engineering development, conducted a detailed analysis of energy consumption monitoring systems (Cao 2018). This analysis led to the delineation of development and implementation processes, including design aspects of data collectors, data communication infrastructure, and the operational functionalities within the software system.

Theoretical framework for carbon accounting in public institutions

In the process of carbon emission accounting for public institutions, these institutions may involve multiple departments, each with potentially different data management processes and methods, leading to data consistency issues and integration challenges. Additionally, the sources of carbon emissions are diverse, with public institutions' carbon emission sources possibly including building energy use, vehicle fuel, staff travel, and the production processes of purchased goods and services. The diversity and complexity of carbon emission sources across different types of public institutions increase the difficulty of accurate accounting. For example, travel within public institutions varies greatly. Government agencies involve staff commuting, business travel for employees, and travel for visitors; schools involve staff commuting, student travel to and from the school (including long-distance travel for universities), and travel for training personnel; hospitals involve staff commuting, patient travel, and accompanying family members' travel; and venues primarily involve staff commuting and travel for visitors (including long-distance travel).

Energy consumption in public institutions primarily encompasses water, electricity, natural gas, district heating, along with minor usage of coal, gasoline, and diesel. These resources are essential for sustaining lighting systems, heating systems, cooling systems, power distribution, elevator systems, as well as specialized energy-consuming units like data centers and cafeterias. Please refer to Fig. 1 for an illustrative diagram.

The carbon emissions assessment for public institutions primarily includes direct carbon emissions from fossil fuel combustion, indirect carbon emissions from purchased electricity and heat, and other indirect carbon emissions. Direct carbon emissions from fossil fuel combustion involve carbon emissions generated by the oxidation combustion of raw coal, natural gas, gasoline, diesel, and liquefied petroleum gas among other fossil fuels. Indirect emissions from purchased electricity and heat encompass the carbon emissions associated with the consumption of purchased electricity and heat by public institutions.

Specifically:

Direct emissions refer to the carbon dioxide emissions generated during the combustion process of fossil fuels used in the operation of public institutions. This primarily includes emissions from the combustion of coal, diesel, gas, natural gas, liquefied petroleum gas, and other fossil fuels.

Indirect emissions are the carbon dioxide emissions generated during the production processes corresponding to the purchased electricity and heat (steam, hot water) used in the operation of public institutions.

Other indirect emissions mainly include:

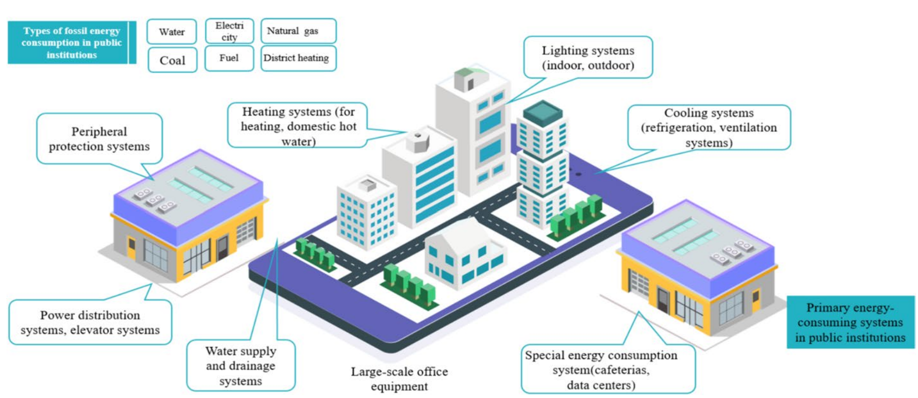

Fig. 1 Illustrative diagram of energy consumption in public institutions

- Consumables: Emissions produced from materials used during the operation of public institutions, such as exhibition materials in museums, teaching materials in schools, medical materials in hospitals, etc.
- Transportation vehicles: Carbon dioxide emissions generated by the commuting of public institution staff using their own vehicles or public transport, as well as emissions produced by external individuals using public transport during the operation of the public institutions.
- Waste: Carbon dioxide emissions generated from the kitchen waste, other waste, recyclable waste, etc., disposed of by permanent and external individuals during the operation of public institutions.

The carbon emissions assessment for public institutions is calculated according to Formula (1).

$$E = E_{fuel} + E_{purchased\ electricity} + E_{purchased\ heat} + E_{other} - E_{output\ electricity} - E_{output\ heat} \quad (1)$$

where:

E—Total carbon dioxide emissions in metric tons (tCO_2);

E_{fuel}—Carbon dioxide emissions from fossil fuel combustion in metric tons (tCO_2);

$E_{\mathrm{purchased\ electricity}}$—Carbon dioxide emissions from purchased electricity in metric tons (tCO_2);

$E_{\mathrm{purchased\ heat}}$—Carbon dioxide emissions from purchased heat in metric tons (tCO_2);

E_{other}—Other indirect carbon dioxide emissions in metric tons (tCO_2);

$E_{\mathrm{output\ electricity}}$—Carbon dioxide emissions from electricity output in metric tons (tCO_2);

$E_{\mathrm{output\ heat}}$—Carbon dioxide emissions from heat output in metric tons (tCO_2).

The relevant data obtained is presented in Table 1.

In the model, the calculation methods for direct and indirect emissions are similar to those commonly used internationally. This paper focuses on summarizing and analyzing other indirect emissions such as travel, waste disposal, consumables of typical public institutions such as government offices, hospitals, and schools. It provides a scope for accountable activities and incorporates them into the overall calculation formula. The carbon accounting model proposed in this paper for public institutions can provide

Table 1 Data for carbon emission accounting for public institutions

Categories	Consumption amount	Emission factors
Direct emissions	Fossil fuel consumption, average lower heating value of fuel	Fossil fuel carbon emission factor
Indirect emissions	Purchased electricity consumption	Electricity carbon emission factor
	Purchased heat consumption	Heat carbon emission factor
Other indirect emissions	Travel distance	Passenger-kilometer emission factor corresponding to the mode of travel
	Amount of waste disposal	Carbon emission factor corresponding to the waste treatment method
	Consumables	Carbon emission factors at the material production stage, carbon emission factors at the material transportation stage

relevant accounting methods tailored to the characteristics of public institutions, enriching the carbon accounting scenarios for such entities.

In the process of carbon emission accounting for public institutions, there are some challenges. First, public institutions may involve multiple departments, each with potentially different data management processes and methods, leading to data consistency issues and integration challenges. Second, there is a diversity of carbon emission sources, which may include building energy use, vehicle fuel, staff travel, and the production processes of purchased goods and services. The diversity and complexity of carbon emission sources across different types of public institutions increase the difficulty of accurate accounting. For example, travel within public institutions varies greatly, including staff commuting, business travel for employees, and visitor travel for government agencies; staff and student commuting, student travel to and from school (including long-distance travel for universities), and travel for training personnel for schools; staff commuting, patient travel, and accompanying family members' travel for hospitals; and primarily staff commuting and visitor travel (including long-distance travel) for venues.

Development of the carbon emission management platform

In China, electricity accounts for over 80% of energy consumption in public institutions, with most of it being converted to carbon emissions. Existing monitoring platforms for public institutions primarily focus on monitoring electricity consumption, neglecting monitoring and carbon emission accounting for transportation, waste disposal, and consumables. This paper proposes a carbon accounting model to construct an information platform that includes direct emissions, indirect emissions, and other indirect emissions. This platform aims to fill the gap in monitoring and managing other indirect emissions in China's existing platforms, providing information support for overall carbon accounting in public institutions.

Based on the accounting model, the carbon emission management platform enables automatic data collection, data analysis, and platform application.

In terms of the overall architecture of the platform: The overall architecture is the technical framework of the platform, providing the basis for the development and functional implementation of the platform. Utilizing a carbon emission accounting model, integrating technologies such as big data, a carbon accounting platform for public institutions is constructed. The system architecture comprises a framework layer, software layer, service layer, business logic layer, and user layer, as depicted in Fig. 2.

- Framework Layer: Primarily provides the hardware foundation for the platform, including servers, storage devices, network equipment, and security devices.
- Software Layer: Offers software and environmental support for platform operation, encompassing databases, web servers, and middleware.
- Standard Support Layer: Provides methodological support for carbon accounting on the platform, including methodologies for direct emissions, indirect emissions, and other indirect emissions.
- Service Layer: Encompasses management modules supporting platform operation, covering users, business rules, report analysis, access control, organizational structure, and event handling.

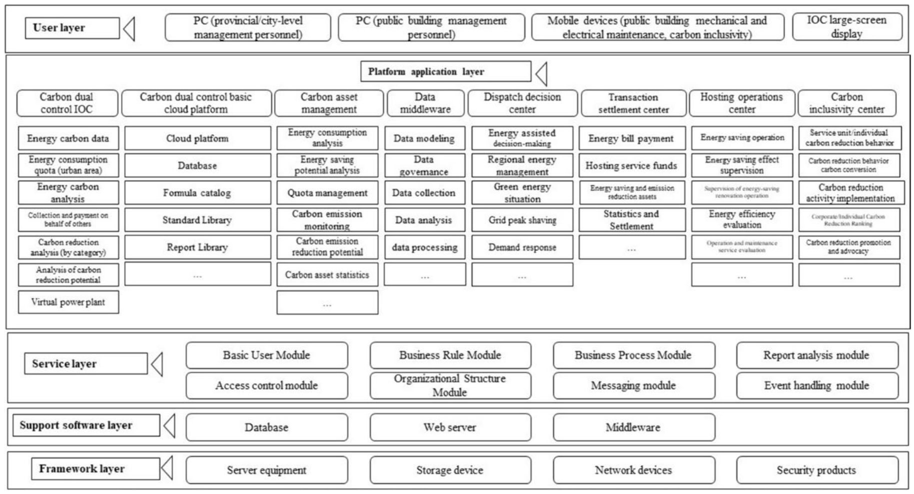

Fig. 2 Architecture of a carbon accounting platform for public institutions

- Business Logic Layer: Supports logical operations for various platform business activities, including carbon dual control, carbon asset management, data middleware, decision-making centers, and inclusive carbon management.
- User Layer: Primarily provides access points for users, including mobile devices, PCs, and IOC large-screen displays.

At the data analysis level: data serves as the core element of carbon accounting, making data analysis a pivotal module of the platform. At the data analysis level, leveraging smart meters for electricity, water, and gas, enables device interconnection to actively and dynamically acquire operational data from public institutions. Additionally, utilizing the Carbon Inclusivity module facilitates the retrieval of transportation and procurement data. Upon entering the data middleware, various algorithms such as accounting algorithm libraries, quota databases, carbon emission factor databases, and environmental building equipment parameter databases are employed for data cleansing and transformation. Through data analysis, carbon emission analysis results are obtained, along with carbon reduction solutions, emission reduction measures, energy-saving operations, and carbon reduction decisions. The data is managed from four aspects: accuracy, completeness, consistency, and reliability. For outliers or erroneous data, they are excluded and warned according to the PauTa criteria; for missing or invalid data, defaults are supplemented and replaced through data cleaning. For data that has not been collected, warnings are issued and manual intervention is conducted. Refer to Fig. 3 for a schematic representation of data analysis.

Platform Application Level: Displaying the services provided for public institutions. The platform establishes an Internet of Things (IoT) middleware, a data middleware, a standard engine, as well as carbon emission statistical monitoring, energy management platform, and Building Information Modelling System (BIMS). Simultaneously, with the support of digital twinning and AI technologies, the platform enables 3D visualization of buildings and intelligent control, facilitating the monitoring and management of quotas and energy consumption for public institutions. It involves the

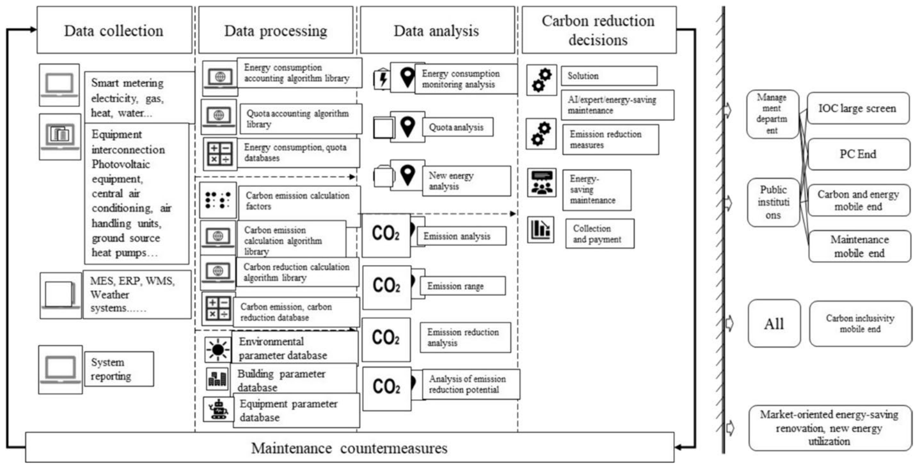

Fig. 3 Schematic diagram of data analysis for a carbon accounting platform for public institutions

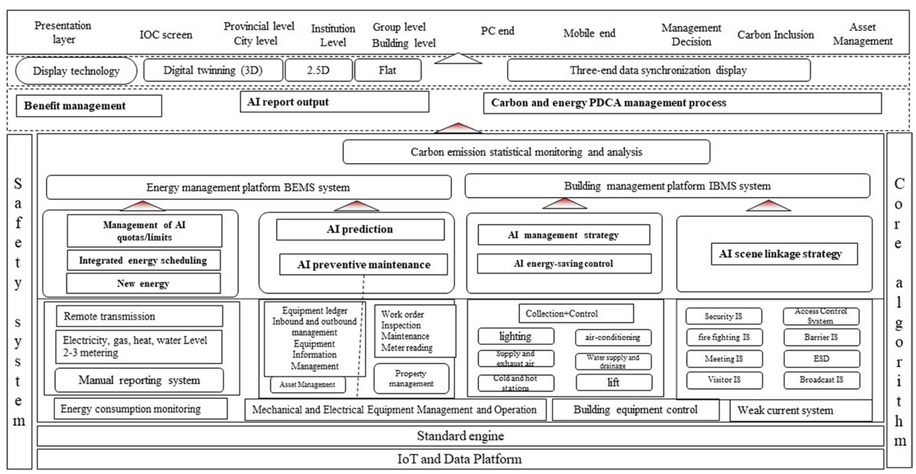

Fig. 4 Application of a carbon accounting platform for public institutions

establishment of operational strategy trees, the formulation of energy-saving control strategies, as well as scenario-based coordinated strategies, all geared towards comprehensive carbon accounting, emissions reduction strategy development, and data analysis for public institutions (see Fig. 4). To ensure the security of public institution data, the platform has established a security system that encompasses user permissions, data transmission encryption, and secure deployment strategies for the system.

The platform is developed using the Java programming language, microservices architecture, and MySQL database. During the application process, firstly, the platform deployment is initiated based on specific requirements of public institutions. Deployment can be conducted via cloud deployment or within the intranet of public institutions. Subsequently, key metering devices such as electricity, water, and gas meters are retrofitted to enable automatic data collection and remote transmission. Thirdly, data is cleansed and transformed through the data layer to facilitate data analysis. Fourthly, carbon emission data is computed and analyzed through the business logic layer. Finally, carbon accounting analysis results are showcased through web interfaces, mobile devices, and other terminals.

Implementation and case study

A certain hospital in China occupies nearly 8 hectares of land with a building area of over 100,000 square meters, housing more than 1,300 beds and employing over 4,000 staff. The outpatient and emergency visits amount to 1.5 million annually. The primary energy sources for the hospital include electricity, natural gas, gasoline, diesel, and water.

Electricity is consumed for heating, air conditioning, lighting, water supply, elevators, and medical equipment. Natural gas is utilized for six gas steam boilers and the cafeteria, providing heat for heating and hot water supply, and steam for medical disinfection. Gasoline and diesel are used for the hospital's vehicle fleet and backup power.

The heating system is equipped with six 8-ton gas steam boilers, providing heat for the entire hospital, refrigeration, hot water for daily use, medical disinfection, and cafeteria needs. The hospital currently has eight sets of central air conditioning systems. The indoor lighting fixtures number around 40,000 lamps with a total power of 1100 kW. The lighting in the outpatient building is used for an average of 12 h per day, while the lighting at nurse stations in individual wards is used for an average of 22 h per day. The hospital has three power distribution rooms—main distribution, surgical distribution, and secondary distribution rooms. Special energy systems in the hospital primarily involve clean operating rooms. The water source is municipal tap water, directly supplied to administrative offices, the main building, cafeteria, and hospital green spaces. The hospital's sewage is treated in a combined system, with wastewater flowing by gravity into external sewage pipes, and basement sewage and firefighting water being pumped out using submersible pumps. The hospital's domestic hot water is produced by heat exchangers with steam from gas boilers, mainly used for bathing. For the hot water system, the hospital employs energy-efficient electric water heaters. There are a total of 24 elevators, including 18 passenger elevators and 6 service elevators, as well as large medical equipment such as scanners.

In accordance with the current state of the hospital, an intelligent transformation of water and electricity meters is proposed to upload all data to a platform for real-time monitoring and management. By using the emission factors embedded in the system from the "Greenhouse Gas Emission Accounting Method and Reporting Guidelines for Public Institution Building Operations (Trial)" issued by the National Development and Reform Commission, the first step is to account for the direct carbon emissions from fossil fuels such as natural gas and gasoline. The second step is to account for indirect carbon emissions from purchased electricity and heat. The hospital's annual carbon emissions are calculated to be 24,481.55 metric tons of CO_2. Within the carbon emission structure, electricity accounts for approximately 56% of the total emissions, natural gas for about 43%, and gasoline and diesel for approximately 1%.

A comparison of the hospital's energy consumption with the local energy consumption quota standards reveals a significant disparity exceeding the regional benchmarks. System analysis suggests implementing rooftop photovoltaic systems to enhance the hospital's overall energy utilization framework. Recommendations include refurbishing the heating system loop pumps, retrofitting the condensate water recovery system within the cooling systems, and piloting a lighting equipment transformation in the emergency building. These adjustments are projected to effectively reduce energy consumption, mitigate carbon emissions, and align the institution with the energy consumption quota standards.

In the case study, during the initial phase of carbon accounting, the hospital faced challenges such as missing metering devices like electricity meters, leading to a lack of metering for key energy-consuming units and equipment throughout the facility. Additionally, the energy, water, and gas consumption records were disorganized, severely impacting the carbon emission accounting for the units and hindering targeted improvements based on carbon emission results. To address this issue, an energy audit was conducted to rectify the missing metering data, and thorough inspections were performed on key energy-consuming units and equipment within the hospital. Subsequently, the management records were organized and analyzed. With accurate and detailed data obtained, thorough data analysis was conducted. The calculated results and carbon reduction pathways were provided to assist the hospital in identifying and addressing issues, uncovering the reasons for previously undetected high energy consumption, and implementing targeted updates. This approach also serves as a valuable experience for other public institutions engaging in carbon accounting, offering practical insights and best practices.

Discussion

In the application process of the public institution carbon accounting model and information platform developed in this study, there are still areas that require improvement, particularly in data collection, accounting costs, and model application.

Firstly, regarding data collection, most existing public institutions in China are established buildings, which exhibit significant variations in energy types and infrastructure. This diversity can impact data collection, especially considering that most metering devices such as water, electricity, and gas meters are mechanical and lack digital remote transmission capabilities, posing a challenge to system implementation. This difficulty can be mitigated by replacing traditional meters with smart meters or implementing data collection and remote transmission devices.

Secondly, in the carbon accounting process for public institutions, direct and indirect emissions are mandatory categories required by regulatory authorities for statistical reporting. However, voluntary reporting for other indirect emissions such as travel and waste disposal leads to low enthusiasm among public institutions. Moreover, the need for additional funding and equipment for the statistical reporting of travel, waste disposal, and other activities further dampens motivation.

Thirdly, this paper emphasizes the statistics and monitoring management of other indirect emissions such as travel, waste disposal, and consumables. The selection of government offices, schools, and other public institutions was primarily based on data availability. While the model methods and platform construction are equally applicable to commercial, tourism, telecommunications, transportation, and other public buildings, challenges arise in data collection. In commercial complexes, tourist sites, and similar public buildings, uncertainties exist regarding the number of people and their behaviors, making it difficult to accurately quantify travel and waste disposal volumes.

Conclusion and future directions

The present study delves into the energy consumption structure and characteristics of public institutions, exploring methodologies for calculating carbon emissions associated with travel and procurement. It standardizes a carbon emissions accounting model for public institutions, leveraging a standardized approach embedded within a carbon accounting platform. Through an analysis of a specific hospital's current status and the application of big data algorithms, carbon emissions are computed, offering recommendations for carbon reduction paths. The focus of this study lies in the methodology of other indirect emissions, enriching the carbon accounting methods for public institutions in China and providing methodological and platform support for carbon emission management in these institutions. The next step will involve the carbon emission accounting for travel, which will delve into detailed analyses of walking, cycling, subway, bus, electric vehicles, and other specific modes of transportation. Through single or combined forms, carbon reduction amounts will be calculated. Additionally, categorization of teaching, medical, exhibition, and other consumables will be conducted for a more detailed calculation of carbon emissions. Research will also be conducted on the classification and measurement of household waste for comprehensive accounting throughout the process. In addition, refining methodologies pertaining to office practices, procurement strategies, and daily living patterns. This approach aims to highlight the distinctive behaviors of personnel within public institutions, thereby providing technical support for comprehensive carbon accounting in such settings. Furthermore, it serves as a representative case study for China's dual carbon goals, advancing the high-quality implementation of dual carbon initiatives within the country.

Author contributions

Y.B. wrote the main manuscript text; R.Z. contributed to investigation; B.Y. contributed to methodology; L.Z. contributed to funding support; J.G. contributed to analysis; Y.M. contributed to manuscript editing and reviewing.

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Availability of data and materials

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no potential competing interests.

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References

Cao M (2018) Design and implementation of energy consumption monitoring system for public buildings. University of Electronic Science and Technology of China

Chen Y, Fang Y, Feng W, Zhang Y, Zhao GX (2022) How to minimise the carbon emission of steel building products from a cradle-to-site perspective: a systematic review of recent global research. J Clean Prod 368:133156
Chen ZS, Huang YD, Zhang Y (2023) Discussion on statistical and calculation methods of transportation carbon emissions. West China Commun Sci Technol 07:204–206
Fan FY, Lei YL (2016) Decomposition analysis of energy-related carbon emissions from the transportation sector in Beijing. Transp Res Part D Transp Environ 42:135–145
Feng QY, Chen CB, Gao S, Li JC (2019) Design of energy consumption data collector system based on RK3288. Electron Meas Technol 42(20):125–129
Huang Y, Guo HX, Xie PC, Liao CP, Zhao DQ (2017) Study on carbon emission reduction calculation of subway travel-take Guangzhou as an example. Clim Change Res 13(03):284–291
Huang ZJ, Zhou H, Miao ZJ, Tang H, Lin BR, Zhuang WM (2024) Life-cycle carbon emissions (LCCE) of buildings: implications, calculations, and reductions. Engineering 35(4):136–160
IPCC (2019) 2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventory [EB/0L]. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/. Accessed 22 Feb 2022
Jiao LM, Guo JD, Hu YX, Liu ZC, Gu ZQ (2023) Research on and application of carbon emission responsibility accounting method for smart home appliances based on benchmark scene. China Stand 05:216–222
Journalist Resource S (2007) United Nations IPCC fourth assessment report on climate change. Global Warming
Li Y, He Q, Luo X, Zhang YR, Dong L (2016) Calculation of life-cycle greenhouse gas emissions of urban rail transit systems: a case study of Shanghai Metro. Resour Conserv Recycl 128:451–457
Li X, Xie Y, Li C, Wang Z, Hopke PK, Xue C (2022) Using the carbon balance method based on fuel-weighted average concentrations to estimate emissions from household coal-fired heating stoves. Chemosphere 307:135639
Lin Z, Yu YY, Wei HB (2019) Design and implementation of wireless heat metering cloud system integrated with ISM and 4G network. Comput Meas Control 27(03):146–149+154
Liu Z, Guan D, Wei W, Davis SJ, Ciais P, Bai J, Peng S, Zhang Q, Hubacek K, Marland G, Andres RJ, Crawford-Brown D, Lin J, Zhao H, Hong C, Boden TA, Feng K, Peters GP, Xi F, Liu J, Li Y, Zhao Y, Zeng N, He K (2015) Reduced carbon emission estimates from fossil fuel combustion and cement production in China. Nature 524(8):335–338
Menezes E, Maia AG, Carvalho CD (2017) Effectiveness of low-carbon development strategies: evaluation of policy scenarios for the urban transport sector in a Brazilian megacity. Technol Forecast Soc Change 114:226–241
Mishalani RG, Goel PK, Westra AM, Landgraf AJ (2014) Modeling the relationships among urban passenger travel carbon dioxide emissions, transportation demand and supply, population density, and proxy policy variables. Transp Res Part D Transp Environ 33:146–154
Onat NC, Kucukvar M, Tatari O (2015) Conventional, hybrid, plug-in hybrid or electric vehicles? State-based comparative carbon and energy footprint analysis in the United States. Appl Energy 150:36–49
Tian YQ (2019) Design and implementation of energy consumption monitoring system. University of Electronic Science and Technology
Wang ZJ, Chen F, Fujiyama T (2015) Carbon emission from urban passenger transportation in Beijing. Transp Res Part D Transp Environ 41:217–227
Yan ZW (2018) Spatial Econometric analysis of the calculation of transportation carbon emissions in china and its influencing factors. Beijing Jiaotong University
Yona L, Cashore B, Jackson RB, Ometto J, Bradford MA (2020) Refining national greenhouse gas inventories. Ambio 49:1581–1586
Yu ZK, Nie Y, Wang Y, Yu DF (2021) Research on the carbon reduction path of green buildings under the dual carbon goals. Resid Ind 10:15–20
Zhang L (2021) Research on carbon emission reduction accounting based on CARBON GSP system for bike-sharing travel-taking Beijing as an example. Urban Public Transp 05:43–46

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