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Life Cycle Assessment of Public Garden Buildings in China: A Case Study of Toilets in the Dongtou National Tourism Demonstration Zone

Imanga Maria Munalula, Rikun Wen*

College of Landscape Architecture, Zhejiang Agriculture and Forest University, 311300 Hangzhou, China

* Correspondence: Riku Wen (wenrk@zafu.edu.cn)

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Abstract: A comprehensive life cycle assessment (LCA) has been conducted to evaluate the environmental impact of a public toilet facility situated in the Dongtou National Tourism Demonstration Zone, China. The study was carried out in accordance with the PAS 2080 standard for carbon management in infrastructure, with digital modelling implemented via Autodesk Revit and carbon accounting performed using OneClick LCA software. Additional calculations related to biogenic carbon sequestration were undertaken using Microsoft Excel, based on nationally and internationally recognized emission factors. The assessment revealed that the most significant contributors to the building's Global Warming Potential (GWP) stemmed from two primary phases: the embodied carbon associated with construction materials and the operational energy use throughout the building's lifecycle. Particular emphasis has been placed on timber components, which demonstrated potential for short-term carbon storage, although this benefit was offset by emissions from material production and transportation. It was further observed that the building's design, operational efficiency, and material selection substantially influenced overall environmental performance. Recommendations are provided regarding the adoption of low-carbon construction materials, the integration of renewable energy sources during the use phase, and the implementation of circular economy principles in waste management. The findings underscore the necessity of adopting an integrated LCA approach to enhance the environmental sustainability of small-scale public infrastructure in sensitive ecological zones. This study contributes to the growing body of evidence supporting carbon-conscious planning and decision-making in the development of public tourism facilities.

Keywords: Carbon neutrality; Life cycle assessment (LCA); Sustainability; Global Warming Potential (GWP); Construction emissions; Carbon storage; Environmental impact

1 Introduction

Through practical applications and ongoing development, life cycle assessment (LCA) has changed into a scientific and systematic assessment methodology, it is used to evaluate the environmental impacts of a product or service throughout its life cycle, from raw material production to final disposal. Initially introduced in the construction industry, LCA has gradually become a primary technique for assessing the environmental impacts of construction projects which include garden buildings. Studies have consistently demonstrated that renovating existing buildings represents a more sustainable approach, fostering economic, social, and environmental win-win situations. LCA has emerged as a pivotal tool in evaluating the environmental impacts of buildings throughout their entire life cycle, from material extraction to demolition. According to ISO 14040, LCA involves compiling an inventory of relevant inputs and outputs, evaluating potential environmental impacts, and interpreting results to inform decision-making processes [1, 2]. Reports indicate that buildings contribute approximately 40% of total energy use and 30% of solid waste generation [1]. Integrating LCA into the design process allows architects and engineers to assess the environmental implications of their choices, promoting a more sustainable approach to building design. LCA serves as a critical decision-support tool that can lead to more informed and environmentally responsible design decisions [3, 4]. Biogenetic carbon accounting has been explained further in this paper. Biogenetic carbon emissions are related to natural carbon cycle. They originate from sources such as plants, trees and soil. CO_2 is captured through the process of photosynthesis and is lost through respiration and stored in biomass and finally sequestered into long-term biological stores in the soil.

This research introduces a life-cycle carbon accounting model specifically designed for assessing the impacts of garden buildings in China. Constructing garden buildings can have both positive and negative environmental impacts, depending on the materials and design choices made. Utilizing sustainable materials, such as reclaimed wood or bamboo, can significantly reduce environmental harm. Incorporating energy-efficient features like proper insulation and solar panels further minimizes the ecological footprint of these structures. Innovative architectural approaches that integrate nature into building designs offer additional environmental benefits. However, it's important to consider potential negative impacts as well. Construction activities can disrupt local wildlife habitats, and the sourcing of non-sustainable materials may contribute to deforestation and biodiversity loss. Therefore, careful planning and the use of eco-friendly materials are crucial to mitigate these adverse effects. Additionally, this research analyzes the carbon emissions associated with construction measures by employing LCA. This paper presents the LCA of a building in China's Dongtou National Tourism Demonstration Zone, conducted using Revit, OneClick LCA software and excel based calculations for biogenic carbon sequestration following PAS 2080 guidelines. This report presents LCA findings, highlighting areas for improvement and strategies for carbon neutrality, while exploring the broader implications of sustainable building practices in the Dongtou National Tourism Demonstration Zone, contributing to a more sustainable construction future.

2 Literature Review

Despite its advantages, several challenges hinder the effective implementation of LCA in building projects. One significant challenge is the long lifespan of buildings, which introduces uncertainties in LCA calculations due to evolving parameters over time [3]. Additionally, variations in calculation tools, system boundaries, and data quality can affect the reliability of LCA results. Many studies emphasize the need for transparency in LCA methodologies and advocate for the establishment of standardized databases to enhance comparability across different assessments [4, 5]. Utilizing local data rather than generic data can also improve accuracy and relevance in specific contexts [3]. The ongoing evolution of LCA methodologies indicates a growing recognition of its importance within the building sector [6]. Future research should focus on refining LCA methods to address existing challenges, such as improving data quality and enhancing transparency in reporting [2, 4]. Moreover, there is a need for innovative approaches that integrate LCA with other sustainability assessment frameworks to create a holistic understanding of environmental impacts. This integration could facilitate better decision-making and promote sustainable practices across all phases of building life cycles [7]. Green buildings help to reduce the impacts on climate and natural environment throughout their design, construction and design process. They are a sustainable alternative to conventional buildings [8]. Some requirements of green buildings, and the corresponding design measures, can directly or indirectly reduce building carbon emissions. For example, solar photovoltaic or more energy-efcient air conditioning systems may be adopted [9]. Recent years have witnessed an increasing focus on the significance of sustainable building practices alongside the reduction of environmental impacts in the construction sector [10, 11]. Green building, which indicates the designing process, construction, and operation of buildings with a priority on energy efficiency and environmental sustainability, is considered a crucial solution in reducing carbon emissions and the environmental impact of the construction industry.

3 Material and Methods

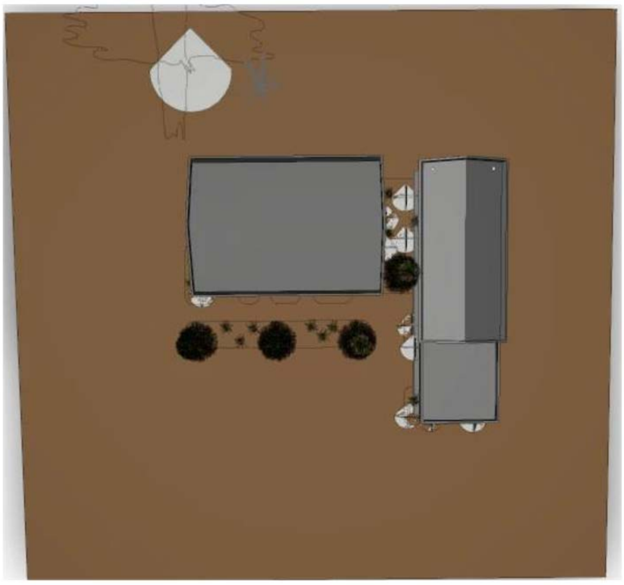
3.1 Building Background and Mode

The building under review in this research is designed as public toilet, with specific attention given to its structural components and materials (Figure 1). It has a gross floor area of 192 m^2. By meticulously evaluating the quantities and dimensions of various building elements, we can gain insights into their environmental impacts. The initial phase involved a detailed review of the Revit model of the building, which provided comprehensive information regarding the dimensions and quantities of various building components. This study used LCA to evaluate the environmental impacts of buildings, following PAS 2080 guidelines. Data collection involved extracting material quantities from Revit models and using OneClick LCA software for calculations. Emission factors from databases were used for biogenic carbon sequestration assessment. The scope included Global Warming Potential (GWP), acidification, eutrophication, and waste disposal, along with biogenic carbon sequestration.

3.2 Quantities of Structural Members in the Building Studied

These components were meticulously documented in an Excel spreadsheet to facilitate accurate input into the LCA software (Table 1). Following the data collection, a detailed inventory was prepared for input into OneClick LCA. This inventory included specifications such as thickness, area, volume, and weight for each material used in the construction process. Key materials include: Concrete which is Utilized in floors, beams, columns, and foundations, with specific mix ratios (e.g., 1:1.5:3 for RCC). Reinforcement Steel is Incorporated in varying percentages across structural elements. Cement, Sand, and Aggregate: Sourced locally to ensure relevance to the project context. Plants related inventory was used within excel sheet and emission factors were used to calculate the biogenic carbon storage/sequestrations.

(a)



(b)

(c)

Figure 1. (a) The front view of the building produced from Revit integrated to OneClick LCA in 3D mode, (b) the top view in 3D mode, and (c) the side view in 3D mode

The inventory also accounted for transportation distances and modes for materials sourced from suppliers in China. The LCA was conducted following the PAS 2080 standard [12], which emphasizes a systematic approach to carbon management in infrastructure projects including building projects. In this case this research focuses mainly on a building project. The assessment was divided into several stages: A1-A3 (Construction Materials): This phase evaluated the environmental impacts associated with the extraction, processing, and transportation of raw materials to the construction site. A4 (Transportation to Site): This stage assessed emissions from transporting materials from suppliers to the construction site. A5 (Construction/Installation Process): This phase analyzed emissions generated during the actual construction activities. B1-B7 (Use Phase): this paper focuses on environmental impacts green buildings therefore, it acknowledges potential emissions during the building's operational phase, including energy consumption and water use. C1-C4 (End of Life): This stage evaluated potential emissions associated with demolition and waste disposal at the end of the building's life cycle.

Table 1. Loading conditions of model and the peak value of earthquake acceleration

Sr. No.	Description	Qty.	Units/Remarks
1	Floor	24.96	m^3
2	Structural Columns	6.88	m^3
3	Beam	11.46	m^3
4	Foundation	7	m^3
5	Wall	72.78	m^3
6	Door	1.90068	m^3
7	Roof	192	m^2
8			Plumbing Fixtures
a	Toilets	2	WCPan-SquattingPan-Vitra-ArkitektSeries-5952
b	WC Dis w Cistern	7	540×360 mm Porcelain/Plastic
c	Toilets	16	Sanitary_Toilets_JohnsonSuisse_Andermatt-Squatting-Pans
d	Urinals	5	600 mm Porcelain
e	Sinks	8	600×2400 mm Fabricated Laminate
f	Urinal divider	5	Sanitary_Screens-Dividers_Roca_M20104053-Divo-Urinal-divide
9	Surface	1673.8	m^2
10			Plants
a	Scarlet Oak Decidous	1	12.5 m height
b	Scotch Pine Tree	4	6 m height
c	Lilly Plant	13	6 m height
d	Shrub	10	1 m height
e	Tea	1	6 m height

3.3 Method

3.3.1 Carbon emission accounting

The method conducted was PAS 2080 and the process include:

• Step 1: Prepare the inventory of the data of each item, by using the revit files for each building.

• Step 2: Next step was to narrow down the inventory, based on the summation of all the quantities against the similar items.

• Step 3: After finalization of the inventory, the emission factors were gathered using the standards by USEPA, IPCC, BSI Standards, IEA Standards etc. for the embodied carbon.

• Step 4: Embodied carbon values were gathered using the emissions factors and quantities in CO_2eq.

• Step 5: For transportation emissions, diesel based vehicle with 7 km/l average was assumed and similarly, truck haulage distance was kept as 70 km, number of haulage times were calculated for each item and using the standard emission factor, the transportation emission were calculated for each item.

• Step 6: For plant use, OneClick LCA software was used, where values of each activity were added and using the standard settings, the results were obtained for plant use at site.

• Step 7: Energy mix was used to calculate the energy emissions.

• Step 8: All emissions were summed up and comparison was made for each building.

• Step 9: Results were presented in the report along with the visual representation via graphs.

The results obtained from OneClick LCA were analyzed to quantify various environmental impact categories, including GWP, acidification potential, eutrophication potential, non-hazardous waste disposed, and biogenic carbon storage. Figure 2 shows the relationship between each stage of carbon, and the associated subcategories, from the perspective of the whole life cycle of a building. Operational carbon refers only to the B6 stage, the carbon emissions from the energy used in the building, and does not include water. Water is not an energy source, and as a resource it is too complex to handle, and for different buildings, water carbon footprint varies greatly and is more suitable for exploration

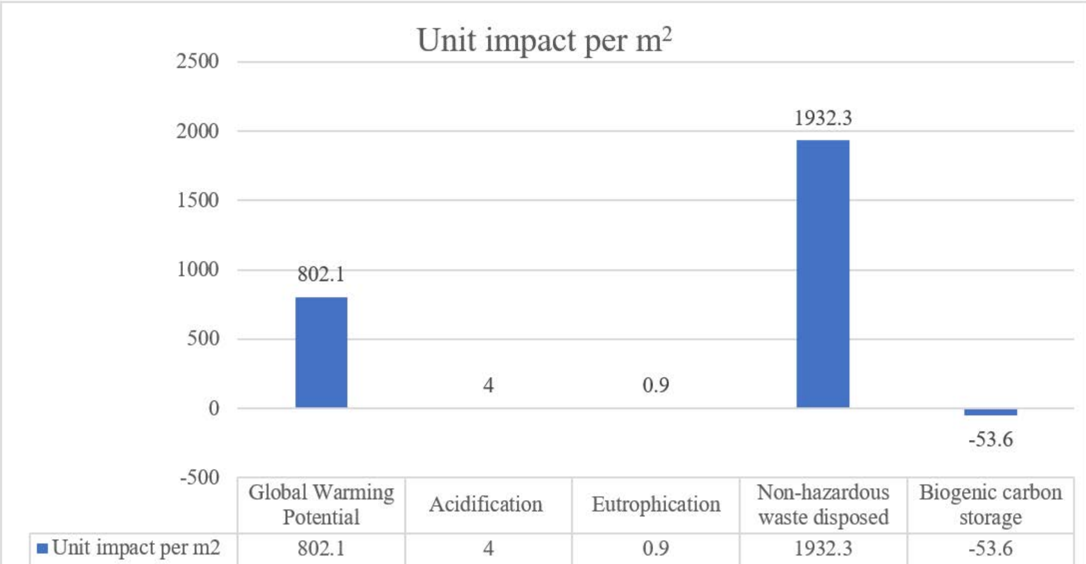


Figure 2. Unit impact per m^2 of building

3.3.2 Biogenic carbon sequestration accounting

Biogenic carbon sequestration is defined as the process by which carbon dioxide is captured and stored by biological systems such as forest, soils, crops, and other vegetation. This paper uses biogenic Carbon sequestration as an example of how carbon dioxide is captured by the plants around the green building. Variations in the inventory of biogenic carbon can be easily ascertained in LCA practices [13]. Some of the importance of biogenic Carbon Sequestration include; Climate Change Mitigation which Reduces atmospheric CO_2 and lowers greenhouse gas emissions. Also, Sustainable Agriculture involve Practices like regenerative farming improve soil health and productivity. Water and Air Quality involves forests and wetlands filter pollutants, enhancing environmental quality. Some of the factors affecting biogenic carbon sequestration may include; Ecosystem Type; Forests, grasslands, and wetlands have different carbon storage capacities. Climate Conditions where Temperature, precipitation, and seasonality affect sequestration rates. Land Use & Management refers to Deforestation, soil degradation, and land-use changes impact carbon retention. Carbon Permanence. This shows that Stored carbon can be lost due to fires, decomposition, or land-use conversion. In this study, the carbon is first sequestered before it is released. The formula to estimate biogenic carbon saturation in garden buildings is given as:

$$BCS = V_m \times \rho_m \times C_f \tag{1}$$

where,

$BCS =$ Biogenic Carbon Saturation ($\mathrm{kgCO_2e}$ stored)

$V_m =$ Volume of biogenic material used (m^3)

$\rho_n =$ Density of biogenic material $\left(\mathrm{kg/m}^3\right)$

$C_f =$ Carbon storage factor ($\mathrm{kgCO_2e/kg}$ of material)

This equation calculates the total amount of carbon stored in the garden building's biogenic materials. Biogenic carbon storage occurs when plants absorb atmospheric carbon dioxide (CO_2) during photosynthesis and convert it into biomass. This stored carbon remains locked within the material until it decomposes or is burned, at which point it is released back into the atmosphere. In garden buildings, wood and other plant-based materials act as carbon sinks, reducing the overall carbon footprint of construction. Factors Affecting Biogenic Carbon Saturation depends on several factors such as material type, material density, building design and life span of materials. Usually for Material Type, different materials store different amounts of carbon. Wood and bamboo are common examples of high-carbon storage materials. Material Density: Denser materials contain more carbon per unit volume. Building Design: Larger garden buildings with more biogenic materials store more carbon. Lifespan of Materials: The longer the materials remain intact, the longer they retain stored carbon, delaying its release. Other basic formulas for calculating biogenic carbon sequestration include:

$$Csequestered = \sum \left(A_i \times G_i \times T_i \times C_f \times (1 - D)\right) \tag{2}$$

where,

$Csequestered =$ Total carbon sequestered (kgCO_2eq or metric tons CO_2eq)

$Ai =$ Area of land covered by vegetation type i (hectares)

$Gi =$ Growth rate of biomass per year for vegetation type iii (kg or metric tons biomass per hectare per year)

$Ti =$ Time duration of sequestration (years)

$C_f =$ Carbon fraction of dry biomass (typically 0.45–0.50 for wood, 0.40–0.45 for crops)

$D =$ Decay or disturbance factor (fraction of stored carbon lost due to decomposition, fires, or land-use change)

Forest Carbon Sequestration is a method that can be used with above ground and below ground biomass storage. The formula is as follows:

$$Csequestered = (B \times C_f \times 3.67) - L \tag{3}$$

where,

$B =$ Total biomass accumulated (tons dry weight)

$C_f =$ Carbon content fraction

3.67 = Conversion factor from carbon to CO_2

$L =$ Carbon losses due to natural decay or disturbances

$$SCO_2 = \rho o \times cc \times 3.67 \tag{4}$$

It is important to know that the derivation of the density of dry biomass (ρo), expressed in $\mathrm{kg/m^3}$, depends on the moisture content (mc) and can be expressed according to the following equation with $mc \geq 25\%$. In the absence of moisture content information, solid and laminated forest products for interior applications can be assumed to have $mc = 20\%$; solid flooring $mc = 15\%$, bio-based panels and insulation $mc = 10\%$.

$$\rho o = \rho mc \leq 25 \cdot \frac{100 + 0.45}{100 + mc} \tag{5}$$

where,

ρo is the biomass density at 0% moisture content $\left(\mathrm{kg/m^3}\right)$

$\rho mc \leq 25$ is the biomass density at moisture content $\leq 25\%$ $\left(\mathrm{kg/m^3}\right)$

mc is the moisture content in the biomass (%)

Some studies demonstrate that not all biobased products can be considered as carbon neutral. Specifically, timber products (e.g. wood that has been processed into beams or planks) have a longer rotation period due to slow forest growth periods, so they cannot be considered as carbon neutral, in a short time horizon [14]. Fast-growing bio-based materials, such as straw and hemp, have a short rotation period and can provide an effective mitigation effect on GHG emissions by rapidly removing carbon from the atmosphere. In other words, Carbon storage can be defined as the sequestration of carbon in products for a certain period of time, resulting in a (temporary) reduction of the CO_2 concentration in the atmosphere [15]. There are several ways of biogenetic carbon accounting. Here are some examples of methods based on Global warmimg potential (GPW); (i) Fixed GWP, which assigns the same characterization factor irrespective of the time at which the uptake/emission occurs; (ii) Zero-GWP, which assigns a characterization factor of 0 to any biogenic CO_2 flow; methods used in carbon footprint standards include; (iii) ILCD [16] and (iv) PAS 2080 (v) biogenic global warming potential (GWPbio) factors [17] that integrate the effect of timing of C sequestration in both terrestrial and anthroposphere sinks; and (vi) DynLCA [18] that accounts for the effect of timing of CO_2 flows using an accounting-based method considering both emissions and sequestrations over time. This study focused in the method PAS 2080 Additionally, different time-related assumptions were analysed, namely the time window of the Global Warming (GW) assessment (fixed or variable), the timing of CO_2 uptake in the forest (past growth, regrowth, no accounting) and in the anthroposphere, and the setting of the initial boundary which is temporal (at plantation or at harvest) and corresponding timeframe of GW effects.

4 Results and Discussion

The LCA conducted for the building in the Dongtou National Tourism Demonstration Zone yielded significant insights into the environmental impacts associated with its construction and operation. This section presents the results of the assessment, followed by a discussion of their implications for sustainable building practices. The findings of this research show that construction materials and energy consumption significantly contributed to GWP, with material production and construction activities driving acidification and eutrophication. Construction generated substantial non-hazardous waste, and landscaping measurably offset CO_2 emissions through biogenic carbon sequestration.

4.1 Results

The results from OneClick LCA are categorized into various environmental impact categories, as summarized in Table 2.

Table 2. Environmental impacts of building

Phase	Results Categories	Global Warming Potential $kgCO_2e$	Acidification $kgSO_2e$	Eutrophication $kgPO_4e$	Non-Hazardous Waste Disposed kg
A1-A3	Construction Materials	33,600	100	24.1	17,900
e A4	Transportation to site	1,230	6.04	1.37	1,700
e A5	Construction/installation process	50,400	75.4	13.3	106
B1	Use Phase	0	0	0	7,720
B2	Maintenance				
B4-B5	Material replacement and refurbishment	3,010	18	2.82	6,020
B6	Energy Consumption	57,700	521	124	147,000
B7	Water Use	6,700	46.1	10.6	11,600
C1-C4	End of Life	1,030	6.06	1.30	187,000
	Totals	154,000	773	177	371,000
	Unit impact per m^2	802.1	4.0	0.9	1932.3

Table 3. Biogenic carbon sequestration by plants

	Plants		Qty.	CO_2 Sequestration Factors (kg)	CO_2 Sequestration (kg)
a	Scarlet Oak Decidous	12.5 m height	1	2178	2178
b	Scotch Pine Tree	6 m height	4	908	3632
c	Lilly Plant	6 m height	13	21.53	279.89
d	Shrub	1 m height	10	131.78	1317.8
e	Tea	6 m height	1	2853.2	2853.2
			Total		10,260.89
			Unit impact per m^2		53.6

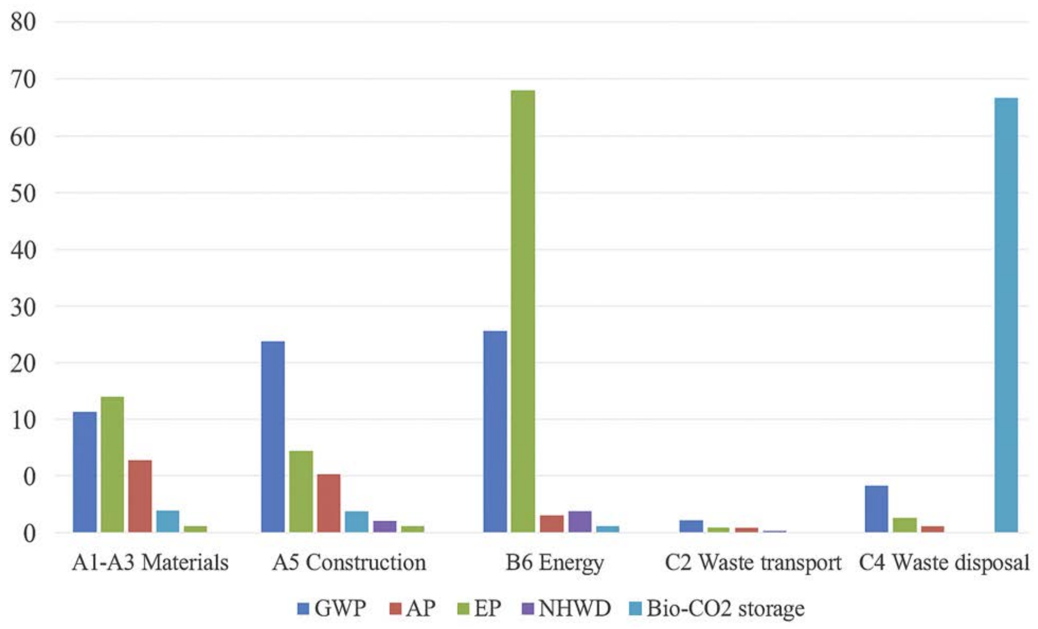


Figure 3. Modules for conducting a life cycle assessment of building

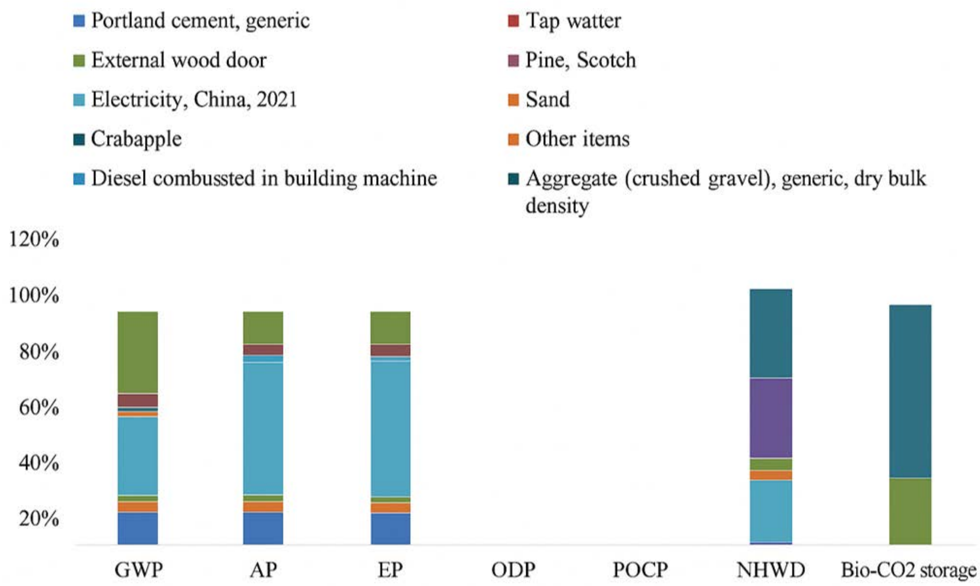


Figure 4. Material-wise breakdown of carbon emissions

The total GWP for the case building throughout its life cycle is estimated at approximately 154,000 kg CO_2e. The highest contributions to GWP arise from the construction phase (A1-A3), accounting for about 33% of total emissions. Notably, the energy consumption during the use phase (B6) represents a significant portion of emissions at approximately 37%, highlighting the importance of energy-efficient design and operational strategies. The assessment revealed that acidification potential is primarily driven by emissions during the construction and installation processes (A5), with a total of 773 kg SO_2e across all phases. Eutrophication impacts were relatively low at 177 kg PO_4e, indicating that nutrient runoff from construction activities may not be a major concern in this project. The total non-hazardous waste disposed of throughout the life cycle is approximately 371,000 kg. This figure underscores the need for effective waste management strategies during both construction and demolition phases to minimize landfill contributions. The assessment also indicates a biogenic carbon storage potential of around 10,260 kg CO_2e bio, primarily attributed to the use of solid wood doors and landscaping elements such as trees and shrubs. This highlights an opportunity for enhancing carbon sequestration through careful selection of materials and vegetation. Table 3 highlights results of the carbon sequestration of the plants obtained from the LCA plugin intergrated to Revit software.please note that the results shown above are only for the plants around the building. The results lead to many suggestions mentioned in the paper and what future suggestions to be taken into consideration. Figure 3 highlights the life cycle stage results obtained during the assessment, and Figure 4 clearly shows the how material break down of carbon emissions during the life cycle assessment.

4.2 Discussion

4.2.1 LCA findings and future suggestions

The findings from this LCA underscore the critical role that each phase of a building's life cycle plays in its overall environmental impact. The significant contributions from energy consumption during the use phase emphasize the necessity for integrating energy-efficient technologies and sustainable practices in building operations. Moreover, the substantial amount of non-hazardous waste generated calls for improved waste management practices on-site and during demolition to reduce landfill contributions. Strategies such as recycling materials and utilizing modular construction techniques can significantly mitigate waste generation. The results also highlight the potential benefits of incorporating biogenic materials into building design to enhance carbon storage capabilities. By selecting sustainably sourced wood products and integrating green spaces into urban environments, we can further contribute to carbon neutrality goals. LCA has been used to provide inputs for green material/product labeling system and consequently helps to optimize the building design [19–22]. The findings from this LCA underscore the critical role that each phase of a building's life cycle plays in its overall environmental impact. The significant contributions from energy consumption during the use phase emphasize the necessity for integrating energy-efficient technologies and sustainable practices in building operations. This aligns with previous research highlighting the long-term environmental benefits of energy-efficient building designs. Strategies such as optimizing insulation, utilizing high-performance windows, and integrating smart building management systems can significantly reduce energy consumption during the use phase. Moreover, the substantial amount of non-hazardous waste generated calls for improved waste management practices on-site and during demolition to reduce landfill contributions. The results also highlight the potential benefits of incorporating biogenic materials into building design to enhance carbon storage capabilities. By selecting sustainably sourced wood products and integrating green spaces into urban environments, we can further contribute to carbon neutrality goals.

The high GWP during the construction materials phase (A1-A3) indicates the importance of material selection. Using materials with lower embodied carbon, such as recycled aggregates or alternative cementitious materials, can substantially decrease the environmental impact of construction. Furthermore, optimizing material quantities through efficient design can minimize waste and reduce the overall carbon footprint. The transportation phase (A4), while smaller in comparison, also presents opportunities for improvement. Utilizing local suppliers and optimizing transportation logistics can reduce emissions associated with material transport. The study's findings regarding acidification and eutrophication potentials, although relatively low, should not be overlooked. These impacts are often associated with industrial processes and agricultural activities related to material production and construction site runoff. Implementing best management practices to control erosion and sedimentation, as well as sourcing materials from suppliers with environmentally responsible practices, can help mitigate these impacts. The biogenic carbon storage potential of the building, primarily attributed to wood elements and landscaping, highlights an important aspect of carbon sequestration. Integrating more vegetation into the building design, such as green roofs or vertical gardens, can further enhance carbon storage and provide additional environmental benefits, such as improved air quality and reduced urban heat island effect. The use of sustainably sourced wood products ensures that the carbon stored in the wood remains sequestered for the long term, contributing to climate change mitigation. This study's application of LCA in the context of a public building in the Dongtou National Tourism Demonstration Zone provides valuable insights for promoting sustainable construction practices in China. The results can inform decision-making processes for future building projects, encouraging the adoption of environmentally friendly materials, energy-efficient designs, and effective waste management strategies. Furthermore, the study contributes to the growing body of knowledge on LCA in the building sector and highlights the importance of considering the entire life cycle of a building when assessing its environmental impact [23–27].

4.2.2 Results from the search compared to other researchers

This research shows that the high GWP during the construction materials phase (A1-A3) indicates the importance of material selection. Using materials with lower embodied carbon, such as recycled aggregates or alternative cementitious materials, can substantially decrease the environmental impact of construction. Furthermore, optimizing material quantities through efficient design can reduce waste and reduce the overall carbon footprint. The transportation phase (A4), while smaller in comparison, also presents opportunities for improvement. Utilizing local suppliers and optimizing transportation logistics can reduce emissions associated with material transport. The study's findings regarding acidification and eutrophication potentials, although relatively low, should not be overlooked. These impacts are often associated with industrial processes and agricultural activities related to material production and construction site runoff. Implementing best management practices to control erosion and sedimentation, as well as sourcing materials from suppliers with environmentally responsible practices, can help mitigate these impacts. Unlike other researchers, this report clearly advices future reviewers or reseachers that the use of sustainably sourced wood products ensures that the carbon stored in the wood remains sequestered for the long term, contributing to climate change mitigation. The use of LCA in the context of a public building in the Dongtou National Tourism Demonstration Zone provides valuable insights for promoting sustainable construction practices in China. The results can inform decision-making processes for future building projects, encouraging the adoption of environmentally friendly materials, energy-efficient designs, and effective waste management strategies. Furthermore, the study contributes to the knowledge on LCA in the building sector and highlights the importance of considering the entire life cycle of a building when assessing its environmental impact. The LCA was used in this research because it provides a reliable picture of material and building environmental impacts. It is clear that the equipment, technical measures, or design objectives required by the Assessment Standard for Green Buildings have the effect of reducing building carbon emissions, regardless of whether they are direct or indirect carbon reduction requirements.

Studies on embodied carbon and carbon emission of construction materials from other researchers are intensively taking place for example the Indian infrastructure sector is associated with carbon emission, which is to be immensely optimized to control the carbon emission. The study has exposed a few materials widely used in the construction sector that are the major contributors of carbon footprint to the environment. These materials' utilization should be controlled and lots of changes in the manufacturing process. Cement, sand, coarse aggregate, fine aggregate, steel, timber, and bricks should be used in reduced quantity and avoided in unwanted places. These materials contribute 98% of carbon in total emission in the construction sector. Also, they contribute environmental pollutants in production places. According to this research, it was noticed that under GWP, the construction materials phase (A1A3) contributed significantly to GWP due to the high embodied carbon in concrete and steel. Energy use during operation also showed a notable impact. Construction materials and energy consumption significantly contributed to GWP, with material production and construction activities driving acidification and eutrophication. Construction generated substantial non-hazardous waste, and landscaping measurably offset CO_2 emissions through biogenic carbon sequestration. For the Acidification and Eutrophication Potentials, these impacts were primarily driven by emissions during material production and construction activities. Non-Hazardous Waste Disposal was noticed that a significant amount of waste was generated during construction, emphasizing the need for effective waste management strategies. Finally, in the Area of Biogenic Carbon Sequestration: Landscaping elements provided a measurable offset to CO_2 emissions, demonstrating the value of integrating green infrastructure into building projects unlike other research papers.

Many research has been done on carbon emission in green buildings all over the world but few researchers focused on carbon emissions of Chinese green buildings. This makes this research useful for garden buildings in China. It also stands a higher chance of proving that the use of timber can be one of the best way of reducing carbon emission in construction. For example, in multi-storey wood buildings, the better environmental performance regarding GHG-emissions followed by modularized structures, and finally beam and columns as the least preferred option [28]. In general, increasing wood use in multi-storey buildings would lead to GHG-reduction benefits [29–31]. However, this increase in wood could raise steel consumption, thus, affecting negatively the GHG-reduction benefits. Also not forgetting that introducing more vegetation around the building is the best way to support carbon neutrality. This paper focused more on carbon emissions and that the use of certain materials are important in the construction industry this is because, the environmental impact of garden buildings largely depends on thoughtful design and material selection. Some studies show that the moment of occurrence of an emission has an influence on the CF in some of the BCA methods, this means that the allocation and BCA methods will not only lead to a different climate change impact of the various products, but also to a different climate change impact of the whole wood cascade system. Whether or not to account for biogenic carbon storage, that is generally temporary, is the subject of ongoing debates [32]. More emphasis is given on the LCA because it plays an important role in this research by providing a reliable picture of material and building environmental impacts. To understand all the impacts associated with a building, it is necessary to look at its life-cycle performance. Life-cycle assessment and life-cycle costing allow to break down the environmental impacts and the cost associated with its life stages. The most known of these metrics is the GWP, or the (life-cycle) carbon footprint. This research paper aimed at calculating carbon emissions of both the building and plants around the building because there was need to analyse if there is a balance in the emissions or rather finding a way to promote carbon neutrality. It been observed that another class of materials named as metal-organic frameworks has received considerable attention to capture CO_2 due to high surface area and flexibility in altering the pore structures and surface properties [33]. When biogenic materials are used in construction, emissions and sequestration of biogenic CO_2 usually occur at very different points in time, but, in most LCA studies, the related climate change effect is not taken into account. Biogenic CO_2 is either not considered or biogenic CO_2 emissions are assumed to balance out CO_2 uptake during biomass growth. To circumvent this issue, a number of dynamic approaches to account for these temporal effects have emerged, focusing on bioenergy at first [34], and encompassing bio-based materials later [35].

5 Conclusions

This report presents a comprehensive LCA of a building located in the Dongtou National Tourism Demonstration Zone, China, utilizing Revit for design and OneClick LCA software for environmental impact analysis. By adhering to the PAS 2080 standard, this assessment has provided valuable insights into the carbon emissions associated with the construction and operation of the building. The results indicate the significant contributions arising from both the construction phase and energy consumption during the use phase. The findings highlight the importance of implementing energy-efficient strategies and sustainable practices to mitigate emissions and enhance overall performance. However, the carbon sequestration plantation is -10,260 kgCOe. Additionally, the assessment revealed substantial non-hazardous waste generation, emphasizing the need for effective waste management practices throughout construction and demolition processes. The potential for biogenic carbon storage through the use of sustainable materials and landscaping further underscores opportunities for enhancing carbon neutrality in building design. In light of these findings, it is clear that integrating sustainability into building practices is not only beneficial for reducing environmental impacts but also essential for achieving broader climate goals. Future projects should prioritize energy efficiency, waste reduction, and sustainable material selection to foster a more environmentally responsible built environment. Ultimately, this LCA serves as a vital tool for informing decision-making in construction, guiding stakeholders toward more sustainable practices that align with global efforts to combat climate change. As the industry continues to evolve, ongoing research and innovation will be crucial in advancing sustainable building practices and achieving carbon neutrality in the construction sector.

From the perspective of carbon emissions, it is even more important to improve the environmental benefits of green buildings and enhance the entire life cycle control effect of green buildings. At the same time, it can reduce building energy consumption, reduce irrational building materials, increase the environmental protection value of buildings, and better protect the ecological environment. Finally, this report emphasizes on carbon reduction measures and effects from the construction industry because they can significantly influence the achievement of overall carbon peak and carbon neutrality targets in not only in China but also all over the world. The findings show that with biogenic emissions and sequestration, the GWP must also address the aspect of sequestration, which is more uncertain and dependent on future management decisions. Future innovations require more research on carbon emissions and should practice more on the use of less carbon materials. The research introduces a carbon accounting model for garden buildings in China, integrating BIM and LCA for efficient assessment. It highlights biogenic carbon, advocates for sustainable materials like reclaimed wood or bamboo, and supports integrating nature into building designs.

(1) It is clear that carbon reduction measures and effects from the construction industry can significantly influence the achievement of overall carbon peak and carbon neutrality targets in China.

(2) Biogenic carbon is considered to be CO_2 neutral and excluded from the inventory analysis, it is accounted for as carbon storage, thus taking into account that CO_2 is captured from the atmosphere during photosynthesis and retained within the bio-based material for a number of years.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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