SUMMARIZING REPORT FOR SCIENTIFIC AND TECHNOLOGICAL RESEARCH PROJECTS

让我们共同打造气候中和的未来
Building a climate-neutral future together

Research on Carbon Emission Database for Building Materials in China

中华人民共和国
住房和城乡建设部

IBE环能科技
中国建筑节能协会
CHINA ASSOCIATION OF BUILDING ENERGY EFFICIENCY

Schweizerische Eidgenossenschaft
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intep
skat Swiss Resource Centre and Consultancies for Development

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Lead Author

Architectural design and Research Institute, XAUAT
- Team Prof. Zhixing Luo

Co Authors

- Team intep-skat
  - Dr. Feng Lu-Pagenkopf
  - Jilong Zhu
  - Dr. André Ullal
  - Roland Stulz
- Team CABR
  - Dr. Shicong Zhang
  - Dr. Xinyan Yang

Content

ABSTRACT

Today, global climate change has become an urgent issue facing the international community. The massive emission of greenhouse gases (GHG) has led to the gradual warming of the Earth's climate, causing such serious problems as the frequent occurrence of extreme weather events, accelerated melting of glaciers, and the continued rise of sea levels. According to the United Nations Environment Program, the building industry, as a major energy consumer, consumes 30-40% of the world's energy and is responsible for nearly 30% of the world's greenhouse gas emissions. Unless we improve the energy efficiency of buildings and effectively reduce their energy consumption and carbon emissions, it is expected that by 2050, greenhouse gas emissions from the building industry will exceed 50% of total emissions.

As one of the main sources of carbon emissions from buildings, accurate calculation of the carbon emissions from building materials has a broad impact on the carbon emissions of the construction industry and the country, and is of great importance in achieving carbon peaks and carbon neutrality in the construction sector. From the perspective of environmental assessment, the accurate calculation of life cycle carbon emissions of building materials is important for green building certification systems such as LEED and CASBEE, and promotes the development of environmentally friendly design and construction technologies. From the perspective of industry transformation, knowing the lifecycle carbon footprint of different materials and construction methods will help construction companies identify and select low-carbon materials and cutting-edge technologies, which in turn will lead to the reduction of carbon emissions across the industry.

The CEF method is currently the most applicable and widely used method for calculating carbon emissions. This method is also applied in calculating the carbon emissions of building materials. In this context, the establishment of a scientific and accurate carbon emission factor (CEF) database for standardized building materials has become a key pillar to achieve this goal, providing strong support for subsequent policy formulation, industry transformation and public awareness.

The present study will undertake a comprehensive analysis of the status quo of China's building materials carbon emission database. It will address the existing policies, standard methodologies, and calculation mechanisms from a macro perspective. Furthermore, the study will assess the environmental impact of China's building materials carbon emission, and explore strategies for quantifying and managing carbon emissions by establishing a database. Secondly, a comprehensive analysis will be conducted on the current status of building materials database construction in China and foreign countries, with a focus on the prevailing challenges. The specific content includes the study of research methods and tools in the field of database construction between China and Europe/Switzerland, and the revelation of the differences and advantages in data collection, processing, and application between the two sides through comparative analyses. The discussion will draw on the experience of Europe, especially Switzerland, in constructing carbon emission factor databases and their advantages, such as the accuracy of data calculation and the diversity of data. The current challenges and development potential of building materials database construction will be discussed in depth. The study methodically analyses and identifies the direction of improvement for China's carbon emission factor database for building materials, and concludes with a series of recommendations for improvement, including improving the official database, enriching the local carbon emission factor database, and improving the transparency of the database.

The objective of the research is to assist practitioners in acquiring a comprehensive understanding of the environmental implications of the construction industry. The study aims to provide scientific references that can inform governmental decision-making and enterprise development, thereby promoting green building practices to a new level and contributing to the national and global goals of carbon neutrality.

1. REVIEW

1.1 Background

Countries around the world are seeking to address the daunting challenge of climate change by controlling carbon emissions to reduce the environmental impact of national development, and reducing carbon emissions has implications for the sustainability and resilience of cities. As the world's largest developing country, China is committed to achieving 'peak carbon' by 2030 and 'carbon neutrality' by 2060.

In the face of the pressing challenge posed by climate change, concerted global efforts are underway to address this issue by controlling carbon emissions with a view to mitigating the environmental impact of national development. The reduction of carbon emissions carries significant implications for the sustainability and resilience of cities. As the world's largest developing country, China is committed to reaching 'peak carbon' by 2030 and 'carbon neutrality' by 2060. In light of this objective, the building materials industry, as a pivotal foundation for national economic and social development, is also among the industries that must be rigorously regulated regarding carbon emissions. Consequently, the analysis and calculation of the carbon emissions of building materials constitutes a fundamental basis for reducing carbon emissions.

According to current research, the construction industry consumes about 60 per cent of the planet's raw materials (Hossain and Poon 2018). In 2019, carbon dioxide emissions from building materials accounted for 10 per cent of total global emissions from the construction industry (Abergel et al. 2019). Concrete is the most widely used building materials in the world, compared to other materials such as steel and wood. Most of the raw concrete materials used in the construction industry contain cement, which emits large amounts of CO_2 during the production process (Wasim et al. 2022). Therefore, reducing carbon emissions from buildings through building materials is one of the ways that cannot be ignored.

The Carbon Emission Report of China's Building Materials Industry (2020), published by the China National Building Materials Federation (CNBMF), highlights that the carbon emissions of China's building materials industry will reach 1.48 billion tonnes in 2020. The report of China Building Energy Consumption and Carbon Emission Research Report (2023), pointed that the estimated carbon emissions from the production and transportation of building materials in China in 2021 are 1.70 billion tCO_2e, constituting 16.0% of the country's total carbon emissions. At the micro level of a building unit, it has been determined that carbon emissions associated with building materials account for between 20% and 30% of the total carbon emissions throughout the life cycle of a building. Focusing on the unit time, the carbon emission intensity of the building materials production stage is the most prominent. The carbon emissions of materials referenced in this study are based on the entire life cycle, encompassing the aggregate of carbon dioxide emissions generated from a series of interconnected processes, including raw material extraction, production, processing, transportation, distribution, construction, installation, utilization, maintenance, and eventual dismantling and disposal. This concept is not only a key measure of the environmental impact of the construction industry, but also the core basis for the development of national emission reduction strategies.

The following table (Li and Chen 2017) shows the emission factors of common building materials in tCO_2/unit, which indicates the amount of CO_2 emitted during the production of one unit of the corresponding material. This table compares the CO_2 emissions from the use of different building materials, further illustrating how knowledge of the carbon emission factors of building materials can guide achieving carbon reductions through material selection. Specifically, the table shows that the production of one tonne of cement releases 0.73 tonnes of CO_2 equivalent. Similarly, pig iron and cast iron have high emission factors (2.3 and 2.5 tonnes of CO_2 equivalent per tonne of material respectively), highlighting the significant environmental impact of these materials.

building materials	**unit**	**Emission factor tCO_2/unit**
cement	t	0.73
raw iron	t	2.3
cast iron	t	2.5
quicklime	t	1.2
sintered brick	m^3	0.14
fired porous bricks	m^3	0.17
aerated concrete block	m^3	0.17
M2.5 masonry mortar	m^3	0.15
M5 masonry mortar	m^3	0.19
M7.5 masonry mortar	m^3	0.22
M10 masonry mortar	m^3	0.26
C20 concrete	m^3	0.23
C25 concrete	m^3	0.25
C30 concrete	m^3	0.27
C35 concrete	m^3	0.29
C40 concrete	m^3	0.31
C50 concrete	m^3	0.35
1:1 Cement mortar	m^3	0.013
crushed stone	t	2

Table 1-1 Emission Factors of Common Building Materials. Source: Xi'an University of Architecture and Technology

In addition, when calculating carbon emissions from building materials, Wang, G. and Luo, T. et al. suggest that the transport of building materials also adds to building carbon emissions. Although this aspect may seem relatively small when assessing the carbon footprint of an individual building, its importance becomes apparent when considering the huge scale of global transport of building materials.

In summary, building materials have a significant impact on carbon dioxide emissions throughout the life cycle of a building, and in fact, building materials can generate carbon dioxide emissions at all phases, from the production of the building materials to their transport, to their construction, to their use, to their dismantling. Therefore, effective measures to reduce CO_2 emissions from building materials should be taken as far as possible during the design, construction and operation of buildings in order to achieve the sustainable development of the construction industry.

1.2 Policy and standards related to carbon emission calculation for building materials

A comprehensive study of the policies and standards related to the whole life cycle carbon footprint of building materials is imperative. Such a study will facilitate the development of suitable evaluation methods and tools for the whole life cycle carbon footprint of building materials, taking into account the unique characteristics of China's national conditions.

1.2.1 Chinese and Foreign Policies

On an international level, the British Standards Institution's (BSI) Carbon Neutrality Attestation Specification PAS2060, published in 2010, incorporates the quantification and management of the carbon footprint (including the product carbon footprint) as a requisite component of the carbon neutrality statement. In June 2022, to align with the stricter emission reduction targets proposed in the EU's European Green Deal, the European Commission adopted a proposal for the Carbon Border Adjustment Mechanism (CBAM). The mechanism was implemented starting from 2023, and formal tariffs will be imposed from 2027. The carbon footprint of products will affect the calculation of carbon taxes.

In accordance with the provisions of the Paris Agreement, Switzerland has committed to reducing carbon emissions by 50% below 1990 levels by the year 2030. Additionally, the nation has established an even more ambitious target of achieving net zero emissions by the year 2050. In terms of legal policy, Switzerland enacted the Carbon Dioxide Act in 2008, which has become a central political instrument for the Swiss government in achieving its greenhouse gas reduction targets (Swiss Federal Office of Energy, 2019). The Building Program, launched in 2010 with the aim of significantly reducing energy consumption and carbon dioxide emissions from Switzerland's building stock, was immediately followed in 2012 by the CO_2 Emission Reduction Ordinance (Swiss Federal Office of Energy, 2019). In Switzerland, the legislative framework encompasses the implementation of specific technical measures aimed at reducing carbon emissions in various sectors, including buildings, transportation, emissions trading, and offsets. The construction materials industry in Switzerland is subject to stringent legal oversight due to the inherent carbon dioxide (CO_2) emissions associated with the production of construction materials.

In China, on 14 September 2022, the General Office of the Ministry of Industry and Information Technology, the General Office of the State-owned Assets Supervision and Administration Commission of the State Council, the General Office of the State Market Supervision and Administration Administration, the Office of the State Intellectual Property Office issued the "Notice on the issuance of the raw materials industry," the implementation of the "three products," the notice put forward: to strengthen the green product evaluation standard implementation, establish a database of carbon emissions of the whole life cycle of key products, and explore the incorporation of carbon footprint indicators of raw material products into the evaluation system.

On 2 November 2022, the Ministry of Industry and Information Technology, the National Development and Reform Commission, the Ministry of Ecology and Environment and the Ministry of Housing and Urban-Rural Development jointly issued the Implementation Plan for Carbon Peak Achievement in the Building Materials Industry (hereinafter referred to as the "Plan"). The Plan mentions the need to track the carbon footprint of key products throughout their life cycle and support the establishment of a big data centre on carbon emissions in the industry; to build a green building materials product system; to incorporate carbon emission indicators for products such as cement, glass, ceramics, lime and wall materials into the green building materials standard system; to accelerate the promotion of green building materials product certification; to expand the supply of green building materials and improve the quality of green building materials products; and to cooperate with the participation of third-party institutions. Give full play to the measurement, standards, certification and other quality infrastructure to support the industry's carbon peak work, including but not limited to the building materials industry carbon emission accounting system, carbon emission measurement system, key industries and products carbon emission limitation standards, energy saving and carbon reduction of new technologies, new technology, new equipment standards, to effectively guide the implementation of carbon emission reduction measures.

In January 2024, the Ministry of Industry and Information Technology and other 10 departments jointly issued the "Implementation Plan for the High-Quality Development of the Green Building Materials Industry" to promote the high-quality development of the building materials industry in a green, low-carbon and safe way. As the market demand increased, more and more consumers and enterprises began to pay attention to the environmental performance of the building, which drove the growth of demand in the green building materials market. In September, the pilot work of product carbon footprint logo certification was carried out to promote the establishment of a unified product carbon footprint logo certification system based on practice under the premise of ensuring data security and to form a typical experience with outstanding benefits that can be replicated and promoted, to actively promote quality certification to empower strong enterprises and strong chains, to help achieve carbon peaks and carbon neutrality, and to promote the overall green transformation of economic and social development to provide a good practice.

1.2.2 Calculation standards of carbon emissions for building materials in China and foreign countries

At present, a perfect accounting standard system has been established in the international arena, while the existing Chinese standards have problems such as unclear accounting scope and boundaries, inaccurate sources of basic data, and fail to reflect the differences between different building materials manufacturing enterprises. Now, the main standards related to the calculation of carbon emissions from building materials at home and abroad are shown in Figure 1-1.

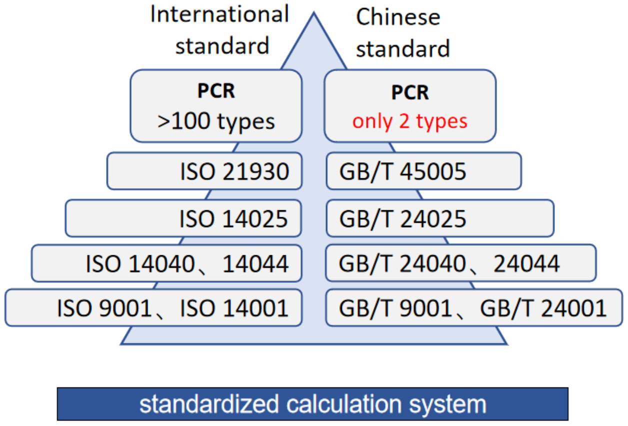


Fig. 1-1 Carbon Footprint Standards for Chinese and International Products. Source: Xi'an University of Architecture and Technology

- International Carbon Calculation Standard for Building Materials

The current international standards specifically related to carbon calculations for building materials are, in descending order of breadth of scope, ISO 9001, ISO 14001, ISO 14040, ISO 14044, ISO 14025, ISO 14067, ISO 21930, and a surplus of 100 rules for product categories.

ISO 9001 is a quality management system certification standard that focuses on how an organisation establishes, implements, maintains and improves a quality management system to ensure that its products and services consistently meet the requirements of customers and applicable regulations. In terms of carbon accounting for building materials, ISO 9001 ensures quality control in the production of building materials, which indirectly affects the management and control of carbon emissions. For example, carbon emissions per unit of product can be reduced by improving productivity and reducing waste. ISO 14001 is an environmental management system certification standard that guides organisations on how to establish, implement, maintain and improve an environmental management system to reduce negative impacts on the environment while ensuring compliance with environmental regulations. ISO 14001 is more directly relevant when it comes to carbon accounting for building materials. It requires organisations to identify and control the environmental impact of their activities, including carbon emissions. An ISO 14001 certified organisation systematically manages its environmental impacts, including quantifying and reducing GHG emissions.

As for ISO 14040 and ISO 14044, of which ISO 14040 provides the principles and framework for Life Cycle Assessment (LCA), it defines the four main phases of LCA: Identification of Objectives and Scope, Life Cycle Inventory Analysis (LCI), Life Cycle Impact Assessment (LCIA) and Life Cycle Interpretation. These principles and frameworks provide a systematic and standardised approach to carbon accounting for building materials, ensuring the transparency, consistency and science of assessment activities. ISO 14044 further refines the specific requirements and guidelines for LCA to implement and conduct LCA. It provides guidance on how to select functional units, system boundaries, life cycle phases, impact categories, and so on. In carbon emission accounting for building materials, these requirements and guidelines help to define the boundaries and methods of accounting and ensure the accuracy and comparability of the results.

ISO 14025 is the international standard for environmental declarations and sets out the requirements for Type III (also known as self-declaration) of environmental declarations. This type of environmental declaration allows a manufacturer or supplier to provide quantitative information on the environmental performance of its products or services. ISO 14025 emphasises the double excellence of product quality indicators and environmental indicators. It requires a systematic analysis of all phases of products and services (e.g. design, production, use, disposal, etc.) in accordance with the LCA theory, to list all the environmental impacts related to the products and services, and to test and calculate the corresponding quantitative results, so as to provide consumers and distributors with comparable environmental information about the products and services. The information is provided to consumers and distributors as comparable environmental information for products and services. In Europe, the standard corresponding to ISO 14025 is EN 15804. In 2019, the standard was updated, of which the one related to carbon emissions of building materials is EN 15804+A2.

ISO 14067 builds on existing international standards, including not only the five principles of PAS 2050, but also the life-cycle perspective, relevant methods and functional units, iterative calculation methods, the order of selection of scientific methods, avoidance of double counting, and participatory and fairness. In terms of data quality requirements, ISO 14067 requires data validation for correctness, sensitivity analysis and qualitative or quantitative uncertainty analyses.The ISO Product Carbon Footprint standard has been discussed at several committee meetings, and ISO 14067:2013 was published in 2013, and ISO 14067:2018

Greenhouse Gas - Product Carbon Footprint - Quantification of the Carbon Footprint of Products was published in August 2018 gases,Carbon footprint of products,Requirements and guidelines for quantification The promulgation of ISO 14067 has formed a market-oriented consensus framework document globally.

ISO 21930:2017 complements the principles and requirements of ISO 14025 for construction products and services.ISO 21930:2017 is a set of principles, specifications and requirements for Environmental Product Declarations for construction products and services, building components and integrated technical systems used in all types of construction.An Environmental Product Declaration (EPD), also known as a subset of Environmental Product Declarations, is a third-party verified, scientific, comparable and internationally recognised report that discloses data on the environmental impacts of a product over its entire life cycle through a Life Cycle Assessment (LCA), including a Global Warming Potential (GWP) indicator converted to carbon dioxide (CO_2) equivalents. EPDs are based on standards 14025 or 21930 (converted to carbon dioxide (CO_2) equivalents) published by ISO, the International Organisation for standardisation. The EPD is an environmental report based on the International Organisation for Standardisation (ISO) 14025 or 21930 standards (depending on the product) and the European 'EN' standards (15804).It does not evaluate the conformity of a product, nor does it compare the advantages and disadvantages of a product, but it helps stakeholders to better understand the integrated environmental impact of a product and its sustainability. When analysing the environmental impact of the whole life cycle of a building, the applicability of the standard is higher than that of ISO 14064 and ISO 14067, and the content of the analysis is better than that of China's current national standard, "Standard for Building Carbon Emission Calculation" (GB/T51366-2049), which is accepted by all countries in the environmental impact analysis of green buildings.EPD certification has been widely promoted and applied in the field of green buildings.

Finally, there are PCRs (Product Category Rules), i.e. Product Category Rules, of which there are currently more than 100 in the international arena, and which are mainly concerned with detailing how to implement the requirements of the LCA to be used as the basis for EPDs. These rules focus on how to model the product system in the LCA, what to include, what data to use, what environmental indicators to report, etc. The purpose of the PCR is to achieve comparability of results between different producers of the same product. c-PRC (constitutes complementary product category rules) refers to complementary product category rules. In the context of environmental product declarations (EPDs), core product category rules (core PCR) and complementary product category rules (c-PRC) together constitute a complete system of rules to guide the preparation of life cycle assessments (LCAs) and environmental product declarations for specific product categories. In short, the PCR provides a set of rules and guidelines for LCA of specific product categories to ensure consistency and comparability of EPDs.

- Chinese Carbon Calculation Standard for Building Materials

Chinese standards related to the calculation of carbon emissions from building materials mainly correspond to international standards, firstly GB/T 9001 and GB/T 24001, which correspond to the international standards ISO 9001 and ISO 14001 respectively, and both are management system standards. In summary, GB/T 9001 indirectly affects the carbon emissions of building materials by improving quality management. GB/T 24001, on the other hand, sets out the requirements for an environmental management system designed to help organisations reduce negative environmental impacts, including carbon emissions from the production of building materials and the building construction process, and is relatively more direct. Together they contribute to the environmental and quality management of organisations, promoting the reduction of carbon emissions from building materials and the sustainable development of the construction industry.

The counterparts to ISO 14040 and ISO 14044 are GB/T 24040 and GB/T 24044, which are equivalent translations of ISO 14040 and ISO 14044. This means that these two national standards in China are consistent in content with the ISO standards to ensure international consistency and compatibility in LCA practices. GB 24025 and GB 24067 are equivalent to ISO 14025 and ISO 14067. Regarding ISO 21930, on 28 November 2024, China published the General Principles for Environmental Declarations for Construction Products and Services (GB/T 45005-2024), which is equivalent to ISO 21930 and will be officially implemented on 1 June 2025.

Chinese current product LCA standards are mainly compiled based on national standards such as GB/T24025-2009 and GB/T 24040-2008 and international standards such as PAS 2050 and ISO 14067, as shown in Table 1-2, and most of them are local standards, mainly concentrated in developed regions such as Beijing, Shanghai and Guangdong.

Type	**Standard**
industry standard	《Technical Guidelines for Product Carbon Footprint Evaluation》 T/GDES 20001-2016
Local Standards/ Beijing	《Technical Guidelines for Evaluation of Low Carbon Products》 DB11/T1418-2017
Local Standards/ Guangdong	《Technical Guidelines for Product Carbon Emission Assessment》 DB44/T1941-2016
Local Standards/ Shanghai	《Product Carbon Footprint Calculating Guidelines》DB31/T 1071-2017

Table 1-2 Carbon footprint standards for our products. Source: Xi'an University of Architecture and Technology

The last is the product category rule, PCR is an important foundation for LCA evaluation to refine and standardise, and move towards practical application, and is also the guideline for the preparation of EPD (Environmental Product Declaration) report. There are still only two national standards for product category rules in China. In 2022, the Shanghai Greenwing Environmental Product Declaration Promotion Centre (EPD Promotion Centre for short) issued EPDCN-PCR-202204 Construction Products and Services Category Rules, in which a large number of building materials are included in the construction products category, including but not limited to concrete, steel, cement, fine stone, blocks and other building materials.

Moreover, the China Building Materials Federation formally endorsed the "Greenhouse Gas Product Carbon Footprint Quantification Methods and Requirements Cement" (T/CBMF 277-2024) and eight additional China Building Materials Association standards, which were published on October 22, 2024, and will be effective from November 1, 2024. The publication and implementation of this standard will accelerate the pace of landing and implementation of carbon footprint accounting rules standards for key products, including cement. The Federation is currently engaged in the construction of a comprehensive database that will serve as a repository for carbon emission factors associated with various cement products. This initiative has been meticulously executed in a phased manner, with each stage of the process being executed in a methodical and systematic manner. The culmination of this endeavor will result in the implementation of a novel system for the purpose of carbon labeling within the domain of construction materials. The implementation of this system will facilitate the integration of carbon footprint accounting and the labeling of enterprises based on their carbon emissions.

1.3 Overview of carbon emission calculation methods for building materials

The scientific calculation of building carbon emission is an effective way to evaluate its environmental load, and the calculation of building carbon emission has always been the focus and difficulty of scholars at home and abroad. At this phase, the commonly used carbon emission calculation methods include the carbon emission factor method, input-output method, material balance method actual measurement method, etc., and the carbon emission factor method is the most widely used method with high authority. The carbon emission factor method is the most authoritative and widely used method at present. Scholars at home and abroad mostly adopt this method to calculate building carbon emissions.

Building carbon emission, from the initial planning and design to the final disposal of the whole life cycle process, will produce resources, energy consumption carbon emissions and other environmental impacts, therefore, from the perspective of the whole life cycle to systematically and comprehensively analyse the level of carbon emissions of these complex product systems and factors affecting the whole society, the whole industry energy saving and emission reduction of great significance. Foreign scholars have also conducted research on building carbon emissions based on the emission factor method combined with the life cycle theory.

1.3.1 Current research status on international carbon emission calculation methods for building materials

Currently, international research on carbon calculation methods for building materials focuses mainly on Life Cycle Assessment (LCA), which is widely used to assess the environmental impacts of building materials throughout their life cycle, including production, transport, use and disposal. However, the delineation and limitation of the calculation boundary varies between organisations.

In terms of the calculation boundary, most scholars focus on the carbon emission of the whole life cycle of building materials; Gustavsson et al. divided the calculation boundary of building life cycle carbon emission into the phases of production and transport of building materials, construction, building operation, demolition and recycling, and calculated the life cycle carbon emission of a wood-framed house as an example; Cho et al. divided the calculation boundary of building carbon emission into the phases of building materials Cho et al. divided the calculation boundary of building life cycle carbon emission into the phases of building materials. divided the calculation boundary of building carbon emission into four phases: production and transport, construction, building operation and building demolition, and conducted a comparative analysis of carbon emission between buildings constructed in the traditional way and low-carbon buildings; Sandanayake et al. used a process-based approach to quantitatively calculate the emissions generated by the production and transport of building materials and the construction and demolition phases, of which the production phase of building materials generates the most building carbon emissions, accounting for 67% of the total. Overall, relatively few studies have focused on the production phase of building materials within the overall topic of building carbon emissions research.

In addition, there are some common features in the international methods for calculating the carbon emissions of building materials: firstly, the standardized methods, for example, EN 15978 describes a calculation method for the Life Cycle Assessment (LCA) of buildings, which includes parameters such as the quantity of materials, service life, implied carbon emissions, etc. Then, there is a need to rely on accurate data. These data are usually derived from national or regional input and output tables, environmental product declarations provided by manufacturers, international databases, etc. Finally, in actual projects it is common to use Bill of Quantities (BOQs) to calculate actual carbon emissions. This method can more accurately reflect the specific conditions of the project.

In summary, the international carbon emission calculation method for building materials has formed a relatively systematic and standardized system, but it still needs to be improved and perfected, for example, the carbon emission factors need to be continuously updated and verified to reflect the latest production technology and environmental standards. The production conditions and energy structure of different regions should be taken into account in the calculation to provide more detailed carbon emission data. Consideration could also be given to combining several technologies to fully assess the environmental and economic impact of building materials in order to adapt to global climate change and the needs of sustainable development.

1.3.2 Current research status on carbon emission calculation methods for building materials in China

In China, carbon emission calculation methods for building materials are mainly researched based on the perspective of full life cycle assessment, and are mainly divided into the following different calculation methods according to specific situations.

- Process-based carbon emission calculation method

This is a bottom-up accounting method, which is often called 'carbon emission factor method', 'emission factor method', 'process analysis method' and so on. It involves a detailed analysis of each link in the building materials production process, including raw material acquisition, transport, processing, and product manufacturing. By determining the energy consumption (e.g. coal, natural gas, electricity, etc.) and GHG emission sources (e.g. carbon dioxide produced by combustion, GHG escaping in the process, etc.) of each link, and calculating the carbon emissions of each link according to the corresponding emission factors, the total carbon emissions of the entire building materials production process are finally summarised.

Based on the basic concepts of the methodology, the carbon emissions per unit of product i or unit of process j can be calculated as follows：

$$E_{i(j)} = \varepsilon_{i(j)} q_{i(j)} \qquad （1\text{-}1）$$

In the formula：

$E_{i(j)}$——Calculated carbon emissions $E_i \ or \ E_j$ per unit of product i or unit of process j ；

$\varepsilon_{i(j)}$——Carbon emission factor per unit of product i or unit of process j, i.e. carbon emissions per unit of activity level；

$q_{i(j)}$——The level of activity per unit of product i or unit process j.

Then, based on the composition of the product system, the carbon emissions E of the product system can be calculated as

$$E = \sum_{i(j)} E_{i(j)} \qquad （1\text{-}2）$$

The current carbon emission calculation for building materials is mainly based on the national standard "Standard for Building Carbon Emission Calculation" (GB/T 51366-2019) which provides a process-based accounting method as well.

- Input-output method

The input-output method calculates carbon emissions from a macroeconomic perspective by analysing the economic links and material flow relationships between the building materials industry and other industries. Specifically, the input-output analysis is guided by certain economic theories and the corresponding mathematical input-output model is established by creating an input-output table that records the input and output relationships between different industrial sectors. In the carbon emissions input analysis based on the value-based input-output model, the carbon footprint of economic activities is analysed by introducing sectoral carbon intensity indicators.

In order to calculate the carbon emissions from building materials, it is necessary to consider the position of the building materials industry in the whole economic industry chain, as well as the energy inputs and carbon emissions in the upstream and downstream industry associations. For example, the building materials industry supplies building materials to the construction industry, and in the construction process of the construction industry, carbon emissions are generated indirectly through the use of building materials products (e.g. cement and steel for building construction). These indirect carbon emissions are calculated by tracking the additional energy consumption and carbon emissions generated by the use of building materials products in other industries through input-output relationships.

- Actual measurement method

The actual measurement method is the most direct method of measuring carbon emissions. It involves the real-time monitoring of GHG emission concentrations and flows at building materials production sites through the use of professional measuring equipment. Theoretically, the basic data of the actual measurement method should be obtained through the scientific and reasonable collection and analysis of representative samples, and the measurement results come from the direct monitoring of carbon emission sources, which can represent the actual level of carbon emissions, and thus have high precision and accurate data. For example, in ceramic tile manufacturers, gas analysers can be installed at the kiln exhaust ports to directly measure the emission concentrations of carbon dioxide, nitrogen oxides and other gases, and at the same time, combined with the exhaust flow rate, the GHG emissions per unit of time can be calculated. In practice, however, it is difficult to apply the actual measurement method in a comprehensive way for the general quantification of carbon emissions due to the limitations of monitoring conditions, measuring instruments and costs.

Overall, the process-based carbon emission calculation method is the mainstream carbon emission calculation method in China and the world. The current national specification "Standard for Building Carbon Emission Calculation" (GB/T 51366-2019) also requires calculation according to this method. Scholars often adopt this method in current carbon emission calculation research, especially in carbon emission calculation research of building materials.

1.4 Challenges for the development of a carbon emission factor database for building materials

At present, the only national standard for building carbon emission calculation is the Standard for Building Carbon Emission Calculation (GB/T 51366-2019), and since the release of this standard, especially after China proposed a carbon neutrality target in 2020 and the Ministry of Housing and Construction (MOHURD) issued GB 55015 in 2021, a large number of architecture design institutes, green building consulting organizations, building developers, building software development units, building materials certification bodies, building materials manufacturers, industry research institutes, etc. have paid great attention to the construction of building materials databases, pointing out the key problems and putting forward higher requirements:

- The comprehensiveness of the database is a significant problem

The types of building materials included in the building materials database of the existing standard cover only more than 70 types of building materials, and this quantity is far from meeting the demand for detailed calculation of building carbon emission. Given the complexity and diversity of the construction industry, there is an urgent need to significantly expand the coverage of the database to include hundreds of common building materials and components and even further refinement to thousands of different specifications. Of particular importance is the small number of carbon emission factors in the Standard for Building Carbon Emission Calculation (GB/T51366-2019), and the obvious lack of consideration of categories such as assembled components and decorative materials, which further highlights the urgency of improving the database. Considering the large volume of construction in China's building industry and the significant contribution of the building materials production and building construction phases to the total amount of carbon emissions, improving the research and calculation of carbon emission factors for building materials, especially the carbon emission factors for assembled components, is crucial to achieving the goal of energy saving and emission reduction in buildings.

- The credibility of the database is of great concern

The carbon emission factor of building materials provided in the current standard is like a ‘black box’, and its opacity seriously affects the reliability and credibility of the calculation results. To enhance the credibility of the data, a transparent and traceable carbon footprint model of the life cycle of building materials should be established to ensure that every step of the calculation is based on evidence, thus improving the accuracy and credibility of the carbon emission results.

- Inadequate timeliness and updating mechanism of the database

The carbon footprints of actual building materials are in a constant state of flux as technology advances and environmental standards improve, requiring the database to be dynamically updated to reflect the latest carbon emissions. In the future, it would be ideal to work directly with building material manufacturers to obtain third-party audited and certified carbon footprint results and to ensure that this information is continuously updated. In addition, the carbon emission factor for the building equipment section needs to be further improved. It should not be limited to materials such as wiring and cables, but should cover various types of electrical and mechanical equipment such as distribution boxes, fans and lifts, which also consume a large amount of energy and materials during the production process, and their implied carbon emissions should not be ignored. Therefore, it is necessary to scientifically calculate the carbon emission factor of construction equipment according to the specific production process and recycling rate of the equipment.

- Intellectual property protection of the database is a prominent issue

According to China's copyright law, even publicly available databases, when used for commercial profit-making purposes, must be authorized accordingly, otherwise, they will constitute an infringement. This legal requirement emphasises the importance of protecting the intellectual property rights of database developers. Only by ensuring that the legitimate rights and interests of the developers are protected, can all parties be motivated to participate in promoting the continuous enrichment, continuous updating and transparent traceability of the China Building Materials Carbon Footprint Database. This is not only related to the healthy development of the database but also a key part of promoting the cause of building energy saving and emission reduction.

To sum up, there are still many problems to be solved in the construction of the building materials carbon footprint database, such as the extensiveness and representativeness of the data sources, the quality of the data in the database, the dynamic updating mechanism of the data, and the protection of intellectual property rights of the database, etc. In this regard, the construction of the database still needs to be completed. For this reason, the construction of the database needs further research, updating the design and management mechanism, etc., to improve the quality of the database, to ensure that it can comprehensively and accurately reflect the carbon footprint of building materials, and help the construction industry to achieve a green and low-carbon transformation, and to promote the realization of the goal of sustainable development.

2. DETAILED METHODOLOGY FOR CALCULATING CARBON EMISSIONS FROM BUILDING MATERIALS

2.1 Detailed Calculation of Carbon Emissions of Building Material in China

2.1.1 General Regulations for Calculating Carbon Emissions of Building Materials

The existing national standards 'Environmental management- Life cycle assessment- Principles and frameworks' (GB/T 24040) and 'Environmental management- Life cycle assessment- Requirements and guidelines' (GB/T 24044) provide standard methods and frameworks for calculating carbon emissions from building materials. According to the above standards, the life cycle accounting boundary for carbon emission calculation of building materials during the phase of production and transport can be 'cradle-to-gate', i.e. starting from the upstream raw materials and energy extraction of building materials, including the whole process of building materials production, and ending at the factory of the building materials, transporting them to the building construction site.

At present, the detailed calculation of carbon emissions from building materials in China is generally based on the formula provided in the Standard for Building Carbon Emission Calculation (GB/T 51366-2019). In this specification, the carbon emissions from the production and transport phase of building materials shall be the sum of the carbon emissions from the production phase of building materials and the carbon emissions from the transport phase of building materials, and shall be calculated in accordance with the following formula:

$$C_{JC} = \frac{C_{sc} + C_{ys}}{A} \qquad (2\text{-}1)$$

In the formula：

C_{JC} —— Carbon emissions per unit of floor area in the production and transport phases of construction($\mathrm{kgCO_{2e}/m^2}$)

C_{sc} —— Carbon emissions from the production phase($\mathrm{kgCO_{2e}}$)

C_{ys} —— Carbon emissions from the transportation phase($\mathrm{kgCO_{2e}}$)

A —— Building area （$\mathrm{m^2}$）

The calculation of building carbon emissions from the production and transport of building materials should include minimum material for the main structure of the building, materials for the building envelope and materials for rough decoration, such as cement, concrete, steel, walling materials, thermal insulation materials, glass, aluminium profiles, ceramic tiles, stone, and so on. Other building materials and new building materials that may appear in the future should also be included in the calculation if they represent more than 0.1% by weight and are produced by energy-intensive processes such as metallurgy and calcination. Components used in assembled buildings are included in the scope of building materials as long as they are outside the building site and are not included in the energy consumption statistics for building construction.

2.1.2 Calculation of carbon emissions from the production phase of building materials

The formula for the production phase of building materials shall be calculated in accordance with the following formula：

$$C_{sc} = \sum_{i=1}^{n} M_i F_i \qquad (2\text{-}2)$$

In the formula：

C_{SC} —— Carbon emissions from the production phase （$kgCO_{2e}$）

M_i —— Consumption of major building material type i

F_i —— Carbon emission factors for major building materials in category i （$kgCO_{2e}$/unit）

By searching design drawings, procurement lists and other technical information related to engineering and construction, it is possible to obtain data such as the bill of quantities and bill of materials of a building, i.e. the amount of different building materials consumed in the construction of the building.

The life cycle boundary of the carbon emission accounting boundary in the production phase of building materials can be adopted as a "cradle-to-gate" model, i.e. starting from the upstream raw material and energy production of building materials to the factory of building materials; including the extraction and production process of raw materials involved in the production of building materials, the transport process of raw materials and energy involved in the production of building materials, and the production process of building materials. and the production process of building materials. If one of the processes is missing or omitted, it should be explained.

Building material companies provide building material production data to third party certification bodies, and the third party certification bodies issue carbon footprint certificates for the companies' building material products, and the certificates indicate the value of the factor (F_i) in the formula of this standard, which can be directly used for calculation. No third party to provide, the default value can be set according to the data given in the appendix of the standard. At present, Chinese and foreign certification bodies have to carry out building materials carbon footprint audit business, the future will be more common, for the building materials part of the carbon emissions calculation provides a convenient.

The use of low-value recycled materials and recycled raw materials in the production of building materials, as well as the recycling of recycled building wastes in the production of buildings, contributes to the reduction of carbon emissions from buildings throughout their life cycle. Where low-value waste materials are used as raw materials, the carbon process of their upstream processes can be ignored and where other recycled raw materials are used, they should be calculated at 50 % of the carbon emissions of the primary raw materials they replace; renewable construction waste generated during the construction and demolition phase of a building can be calculated at 50 % of the carbon emissions of the primary raw materials they replace and should be subtracted from the carbon emissions of the building.

In addition, the determination of the main building materials to be included in the calculation shall be in accordance with the following provisions: the total weight of the selected main building materials shall not be less than 95 % of the total weight of the building materials consumed in the building; if the provisions of the previous article are met, building materials with a weight ratio of less than 0.1 % may be excluded from the calculation.

2.1.3 Calculation of carbon emissions during the transportation phase of building materials

The formula for the transportation phase of building materials is as follows：

$$C_{ys} = \sum_{i=1}^{n} M_i D_i T_i \qquad (2\text{-}3)$$

In the formula：

C_{ys} —— carbon emissions from the production phase($kgCO_{2e}$)

M_i —— consumption of major building material type i （t）

D_i —— average transportation distance for building materials in category i

T_i —— carbon emission factor per unit weight of transport distance for transport mode of building materials of type i $[kgCO_{2e}/(t\cdot km)]$

It is preferable to give priority to the actual transport distance of the main building materials. The carbon emission factor (T_i) for the transport phase of the building materials should include the direct carbon emissions of the transport phase of the building materials from the production site to the building site and the carbon emissions of the production process of the energy consumed in the transport process.

2.2 General methodology for accounting of carbon emission factors

2.2.1 Methodology

There are a wide variety of materials used in the construction sector, and the way in which their carbon emissions are assessed is divided into two main categories. One is based on macro industry statistics, for example, the average carbon emission factor of cement is deduced from the total production volume of cement and the total amount of carbon emissions of the whole cement industry. The other is to accurately calculate carbon emissions based on the specific production process of building materials, a method favoured for its high degree of accuracy and wide applicability. In the following, we will explain the calculation process of carbon emission factor of building materials broken down into five steps for the second method.

- determines measurement boundaries

At present, the accounting of the carbon emission level of building materials generally includes the implicit carbon emission during the production of raw materials, the carbon emission during the transport of raw materials and the carbon emission during the production and processing of building materials. The determination of the accounting boundary should refer to the relevant calculation standards and norms and be combined with the specific production facilities and process flow of the building materials, covering the implicit carbon emissions from raw materials, carbon emissions from fuel combustion, carbon emissions from physical and chemical reactions during the production process of the building materials, carbon emissions from the purchased electricity and heat generated by the company, and carbon emissions from the electricity and heat generated by the company that is exported (i.e. the use of residual heat and the process of coordinated disposal of waste, etc.), as shown in Figure 2-1.

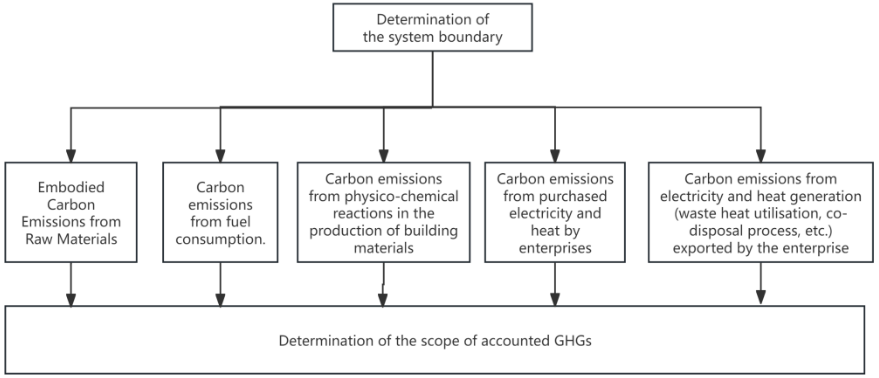


Fig. 2-1 Boundary of carbon emission factor measurement for building materials.
Source: Xi'an University of Architecture and Technology

- Analysis of process flow

Different processes and technologies may be used in the production and processing of building materials, with differences in the methods and processes used to calculate the associated carbon emissions. For example, a dry production line for cement dries and grinds the raw materials before feeding them into a dry kiln to calcine the mature materials, whereas a wet production line grinds the raw materials with water into a raw slurry and then feeds it into a wet kiln to calcine the mature materials, and the two different production processes result in differences in the level of carbon emissions.

- Identifies sources of carbon emissions and types of greenhouse gases

Based on the production process of building materials, the sources of carbon emissions are clearly defined, which generally include the combustion of fossil fuels, physical and chemical reactions in the production process of building materials, and the use of mechanical equipment, such as electricity and oil consumption. Carbon dioxide (CO_2) should be the main GHG for carbon emission measurement, while including but not limited to methane (CH_4), nitrous oxide (N_2O) and other gases. The types of GHGs should be determined based on actual emissions and characterised in terms of CO_2 emissions or carbon dioxide equivalent emissions.

- Choice of measurement method and data collection

After clarifying the sources of carbon emissions, it is necessary to clarify the corresponding measurement methods and data collection. Firstly, the measurement components involved in the production process of the building materials should be clarified in order to refine the measurement formula and the measurement process. Data collection will then take place. For carbon emissions from fossil fuel combustion, the consumption of fossil fuels is generally obtained from the production data book or the fuel consumption monitor of machinery and equipment, etc., which is combined with the calculation of the carbon emission factor of fossil fuels; for carbon emissions from the production process, the carbon emissions are generally determined by chemical analysis and measurement; for carbon emissions from machinery and equipment in use, energy consumption can be obtained from production data records, electricity meter records, etc. and then measured in combination with the corresponding carbon emission factors.

- Calculating the carbon emission factor

The carbon emission factor per unit mass/ volume of building materials can be calculated by dividing the total carbon emission obtained from the collected and aggregated data by the mass or volume of the building materials.

2.2.2 Carbon emission factor calculating formula for building materials

At present, the specific formulae applied in the calculating methods for carbon emission factors may differ, but they are mainly based on the specific production process of building materials to calculate accurately, and some typical representatives will be introduced below.

Firstly, Wu Gang, Ou Xiaoxing and Li Dezhi have studied the carbon emission factor accounting method, and their research idea is the same as the previous section, which is to calculate the carbon emission accurately according to the specific production process of building materials. In the final phase of carbon emission factor calculation, the carbon emission factor of building materials is derived by dividing the total carbon emission by the mass or volume of building materials.

In Xiaocun Zhang et al.'s study, the carbon emission factor of materials is classified according to the difficulty of the production process. For raw materials with simple production processes, the carbon emission factor can be calculated according to the following formula based on the energy consumption of mining and processing as well as direct GHG emissions:

$$EF^m = \sum_p q_p^e EF_p^e + e^d \tag{2-4}$$

In the formula：

EF^m —— Carbon emission factor per unit of raw material （$\mathrm{kgCO_{2e}/unit}$）

EF_p^e —— Carbon emission factors for energy p （$\mathrm{kgCO_{2e}/kg}$ or $\mathrm{kgCO_{2e}/m^3}$）

q_p^e —— Consumption of energy type p per unit of raw material extracted and processed （kg or m^3/unit）

e^d —— Direct GHG emissions per unit of raw material extraction and processing （$\mathrm{kgCO_{2e}/unit}$）

For raw materials with complex production processes, the carbon emission factor can be accounted for according to the LCA theory based on the flow chart. For building materials with no interaction between production processes, the calculation can be simplified according to the following formulae：

$$EF^m = \sum_g \left(\sum_p q_{gp}^e EF_p^e + \sum_r q_{gr}^m EF_r^m + e_g^d\right) \tag{2-5}$$

In the formula：

EF_r^m —— Carbon emission factor per unit of raw material r （$\mathrm{kgCO_{2e}/unit}$）

q_{gp}^e —— Consumption of energy p per unit of material in production process g （$\mathrm{kgCO_{2e}/kg}$ or $\mathrm{kgCO_{2e}/m^3}$）

q_{gr}^m —— Consumption of raw material r in production process g per unit of material （kg）

e_g^d —— Direct GHG emissions per unit of material production process （$\mathrm{kgCO_{2e}/unit}$）

For raw materials that lack detailed production process and inventory data, input-output analysis can be used to estimate carbon emission factors by sectoral embodied carbon intensity:

$$EF^{m} = EF_{i}^{s} p^{m} \qquad (2\text{-}6)$$

In the formula：

EF_{r}^{m} —— Implied carbon intensity of sector I to which the material belongs（$\mathrm{kgCO_{2e}/yuan}$）

p^{m} —— Ex-factory unit price of materials（yuan）

In addition, many other scholars have explored how to improve the quality of factor data, for example, in Zhao and Liu's study, they proposed a carbon emission energy factor (Em-CEF) model based on energy accounting and energy factor, which compares, analyses and calculates the carbon emissions of traditional buildings, green building materials and prefabricated components at the materialisation phase. Among them, the carbon emission factor calculation model for building materials is mainly for concrete buildings. The energy value calculation is used to correct the CEF in different regions and at different times to establish the Em-CEF model. The application formulas of the model are as follows:

$$\sum T_i = \sum M_i \times （1+q）\times \mathrm{f_i} \qquad (2\text{-}7)$$

In the formula：

T_i —— Carbon emissions from category i building materials

M_i —— Total consumption of building materials in category i

q —— Reasonable losses unavoidable during construction

$\mathrm{f_i}$ —— Carbon emission factor for category i building materials or machinery ($\mathrm{kgCO_2/kWh}$ or $\mathrm{kgCO_2/kg}$)。

2.2.3 Example of calculating for cement carbon emission factors

The example in this section is to demonstrate the process of calculating the carbon emission factor of cement as an example using the methodology provided by Wu Gang in his book Carbon Emission Calculation for Buildings.

- Determines the boundary

The cement production process mainly includes raw material treatment, crushing, feed mixing and pretreatment, preheating, decomposition outside the kiln, clinker production, clinker cooling and storage, mixing, grinding and so on.At present, the accounting standards for the measurement of cement carbon emission factors mainly include the ‘Guidelines on Accounting Methods and Reporting of GHG Emissions for Cement Manufacturing Enterprises in China (Trial)’, ‘Requirements for Accounting and Reporting of GHG Emissions Part 8: Cement Production Enterprises GBT32151.8-2015’, ‘Evaluation Methods and Requirements for Low Carbon Products of General Silicate Cement CNCA/CIS0017-2014’, which are the standards for accounting boundaries and calculation methods. These standards have different accounting boundaries and calculation methods. In contrast, the ‘General Silicate Cement Low Carbon Product Evaluation Methods and Requirements CNCA/CTS0017-2014’ is relatively comprehensive, which is used as the basis for this section to introduce an example of cement carbon emission factor measurement. The accounting boundary includes the direct and indirect emissions of the whole manufacturing process from raw materials to products. (hereinafter referred to as ‘Low Carbon Product Evaluation Method’)

- Analysis of process flow

The new dry-process kiln preparation method is the more commonly used method of cement production, and its process can be summarised as follows：

- Raw meal preparation, means the process of mixing/ homogenisation, grinding and preheating of raw meal;
- Clinker calcination, means the process of generating clinker by reacting raw materials at a high temperature of 900 to 1500°C in a preheater and in a rotary kiln;
- Cement grinding, which refers to the process of grinding and homogenising the cooled clinker with additives. As shown in Figure 2-2.

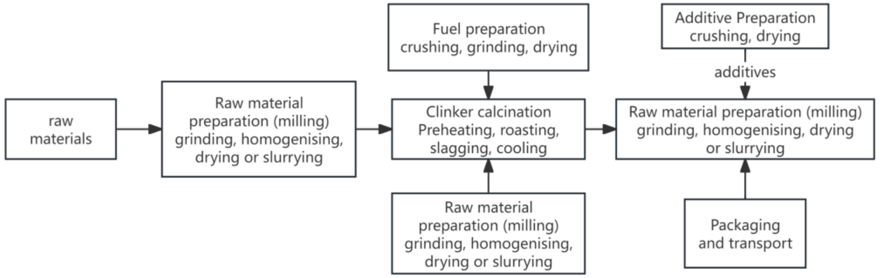


Fig. 2-2 Flow of cement production. Source: Xi'an University of Architecture and Technology

- Identifies carbon emission sources and gas types

Direct carbon emissions from cement production mainly include carbonate decomposition and carbon emissions from the use of fuels in machinery and equipment Indirect carbon emissions mainly refer to the emissions from the consumption of electricity in machines The main GHG emitted during the cement production process is CO_2, so the accounting is mainly for the amount of CO_2 generated.

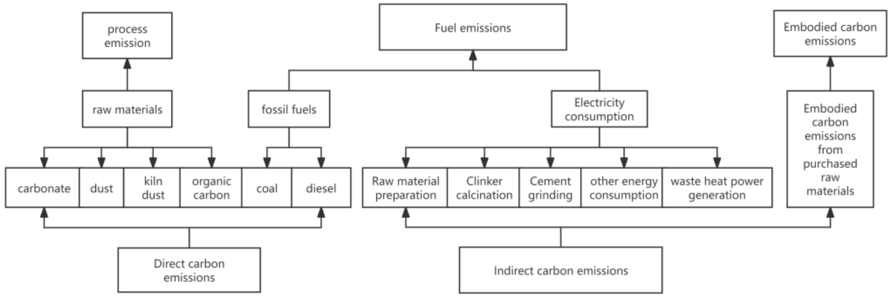


Fig. 2-3 Analysis of Carbon Emission Sources. Source: Xi'an University of Architecture and Technology

- Measurement Methodology and Data Collection

Based on the decomposition of the accounting unit of carbon emissions from the cement production process, the measurement methods are clarified separately. For the CO_2 measurement of carbonate mineral decomposition in raw materials, emission of bypass dust from new dry-process kiln through calcination and emission of cement kiln ash from new dry-process kiln through calcination, chemical analysis is mainly used to calculate the CO_2 gases released from the production process; for the CO_2 generated from traditional fossil fuels (including coal, gasoline, diesel, etc.) and electricity consumption, it is calculated by the amount of consumption and corresponding carbon emission factor; for the carbon emission implied by the purchase of raw materials, it is calculated by the amount of consumption and corresponding carbon emission factor; and for the carbon emission of purchased raw materials, it is calculated by the amount of consumption and the corresponding carbon emission factor. For the implied carbon emissions from purchased raw materials, they are measured by consumption and the corresponding carbon emission factors.

Data collection of a cement company's production in a certain period of time, raw material consumption is obtained by comparing the order and production inventory, fuel consumption and electricity consumption can be obtained by checking the production ledger, electricity meter and fuel meter, and physicochemical attributes such as percentage are obtained by chemometric analysis.

- Carbon emission factor calculation

Carbon dioxide emissions from carbonate mineral decomposition in raw meal (R_1) were calculated, CO_2 emissions from new dry process kiln bypass dust via calcination (R_2), CO_2 emissions from cement dust from kiln exhausts via calcination (R_3), CO_2 emissions from conventional fossil fuels (R_4), CO_2 emissions from combined electricity consumption in clinker production (R_5),CO_2 emissions from electricity consumption in the cement manufacturing process (R_6), Emissions from purchased cement clinker and purchased processed ground slag powder (R_7、R_8), CO_2 emissions from alternative fuels, co-disposal of waste (R_9), and waste heat utilization outside the operational boundary (R_{10}). Finally, after the integration of the calculations can be carried out to calculate the final cement carbon emission factors, which need to be brought into the following formulas:

Calculation of total CO_2 emissions from clinker production processes：

$$T_{ck} = R_1 + R_2 + R_3 + R_{4ck} + R_5 - R_9 - R_{10} \tag{2-8}$$

In the formula:

T_{ck}——Total CO_2 emissions from cement clinker production during the statistical period（t）

R_{4ck}——CO_2 emissions from conventional fossil fuels consumed in cement clinker production during the statistical period (t)

Correction factor calculation of clinker CO_2 emission:

$$K_{ck} = \sqrt[4]{\frac{52.5}{A}} \times \sqrt{\frac{P_h}{P_0}} \tag{2-9}$$

In the formula:

K_{ck} ——Correction factor for CO_2 emissions from cement clinker during the statistical period, dimensionless

52.5 —— Revised average compressive strength of clinker during the statistical period (MPa)

A —— Average 28d compressive strength of cement clinker during the statistical period (MPa)

P_h ——Total clinker consumed during the statistical period for the production of a particular type of cement (t)

P_0 —— Ambient atmospheric pressure at sea level, 101 325 Pa

Comparable emissions per unit of cement clinker：

$$C_{ck} = \frac{T_{ck}}{Q_{ck}} \times K_{ck} \times 1000 \tag{2-10}$$

In the formula：

C_{ck}——Comparable emissions per unit of cement clinker produced during the statistical period（kg CO_2/t）

Calculation of emission factor：

$$C_{ce} = \frac{C_{ck}Q_{ck} + R_6 + R_7 + R_8 + R_{4ce}}{Q_{ce}} \quad (2\text{-}11)$$

In the formula:

C_{ce}——Emissions per unit of production of a particular type of cement during the statistical period (kgCO_2/t)

Q_{ck}——Total clinker consumed during the statistical period for the production of a particular type of cement (t)

Q_{ce}——Total production of a certain type of cement during the statistical period (t)

R_{4ce}——CO_2 emissions from the consumption of conventional fossil fuels in a cement manufacturing process during the statistical period (t)；

Finally, the carbon emission factor of the cement produced by the company was calculated as $C_{ce} = \frac{478\ 448\ 775.4}{846\ 320} = 565.33$ kgCO_2/t。

3. CHINESE CARBON EMISSION FACTORS DATABASE FOR BUILDING MATERIALS

China's energy-saving and emission reduction policies and standardized systems in the building sector have not only stimulated the market demand for carbon emission calculations for the whole life cycle of buildings, but also provided a strong impetus for the construction of a carbon emission database for buildings in China.

3.1 Representative carbon emission factors database

In the cutting-edge field of building carbon emission calculation in China, Donghe Carbon Emission Calculation and Analysis Software (hereinafter referred to as "Donghe Software") and Green Building Swire Carbon Emission Calculation and Analysis Software (hereinafter referred to as "Swire CEEB") have become two popular software programs in the market with their wide application and rapid development momentum. CEEB (hereinafter referred to as "Swire CEEB"), with its wide range of applications and rapid development momentum, have become two popular software programs in the market. In addition, there are many other databases, such as Chinese Life Cycle Database (hereinafter referred to as "CLCD") and China Product Life Cycle GHG Emission Factor Set (hereinafter referred to as "CPCD Database"). In recent years, the newly developed Ouroboros Building Carbon Emission Calculation and Monitoring Software (hereinafter referred to as "Ouroboros") also has quite detailed data and various functions. These databases are developed based on the design needs of engineers, focusing on China's current relevant standards, and covering the entire life cycle of buildings.

3.1.1 Donghe Software

Donghe Building Carbon Emission Calculation and Analysis Software, jointly developed and promoted by Southeast University and China Construction Group, is an early lightweight building carbon emission calculation and analysis software in China. This software does not need to install huge and complicated modeling software in advance, and it can directly enter the basic information of the building and the information of energy, resource consumption and waste emission at each phase, and also import the results of mainstream commercial software, with obvious features in light weight and specialization. It can also import the results of the mainstream commercial software, with obvious features of light weight and specialization. Meanwhile, it can be applied to multiple building types and climate zones, and provide carbon emission calculation results of different granularity, supporting dynamic accounting of building carbon emission and intelligent decision-making on carbon emission reduction for different types of users.

Version 2.0 was released on March 25, 2022, which is a major functional upgrade version under cooperation with leading enterprises in the industry, such as China Construction Group. An order of magnitude upgraded the capacity of the carbon emission factor library, the software architecture and building carbon emission calculation and analysis functions were significantly upgraded, blockchain technology was introduced to ensure the authenticity, reliability and non-tampering of the calculation and analysis, and innovative business processes were introduced.

Version 3.0 was released on October 22, 2023, on the occasion of the 100th anniversary of the founding of the Civil Engineering Discipline of Southeast University and the conference on high-quality development, with a comprehensive improvement of software performance, modularisation and completeness of display and calculation indices based on user use, and the introduction of some key aspects below.

- Volume of date

With the iteration of versions, especially version 2.0, the capacity of the carbon emission factor library has been significantly enhanced. It covers carbon emission factors related to various types of materials, energy, processes, etc., involved in each phase of the whole life cycle of a building. For example, for building materials, it contains detailed carbon emission factor data from production to transportation of common materials such as cement, steel, wood, glass, etc., amounting to thousands of entries. For energy types, factors related to the production and installation of solar photovoltaic (PV) modules are included, from traditional electricity, coal, and natural gas to emerging renewable energy sources such as solar photovoltaic (PV) modules. This rich volume of data provides a solid foundation for accurate calculation of building carbon emissions.

During the software development process, a large amount of building model data of different types (e.g., residential, commercial, industrial, and public buildings, etc.), scales (from small residential houses to large complex buildings), and climatic zones (severe cold, cold, hot summer/winter, hot summer/winter, mild areas, etc.) were collected and analysed. This amount of data is not only used for the optimisation and validation of the software functions but also provides users with a wealth of reference cases when using the software, helping them to better understand and adjust the input parameters in order to obtain calculation results that are more in line with the actual situation.

- Data format

Input data format: The software has clear format requirements for the entry of basic information about the building. For example, the geometric dimensions of the building are entered in the form of numerical values of length, width, and height, with units selectable from international standard units (meters). The functional type of the building is selected through a drop-down menu, including standard classifications such as residential, office, shopping mall, etc. Such a unified format facilitates the software's accurate identification and subsequent calculation. Energy consumption data, e.g., electricity consumption, can be entered in a time series (e.g., monthly or yearly consumption) in tabular form in kWh. Building material consumption can be entered in the format of the name of each material and the amount (mass or volume unit, e.g., tons, cubic meters). Meanwhile, it supports importing data from other mainstream building design or energy simulation software (e.g. Revit, Ecotect, etc.), and the format of the imported data follows the international or Chinese common building information modelling (BIM) standard or the data exchange format of the specific software, which ensures the compatibility and accuracy of the data.

Output data format: The calculation results of the software are output in the form of a report: the report format is standardised and rich in content, including building carbon emission overview, the basis of carbon emission calculation (the source and version of the carbon emission factor used), and the results of the calculation of carbon emission at each phase (in the form of a table and a chart), and so on. In the tables, the carbon emission values of each phase of the building life cycle (e.g. material production, transportation, construction, operation, demolition) are listed in detail in $kgCO_2eq$ and can be displayed with different precision (e.g. retaining one decimal or integer) according to the user's needs. Graphs and charts are available in the form of bar charts and line graphs to visualise the percentage of carbon emissions at each phase and the trend over time, making it easy for users to quickly understand the key information on building carbon emissions.

Data Storage Format: The software supports storing the calculation results in various formats, such as the common PDF and Excel formats. PDF format is convenient for users to print and share the report, while Excel format is more conducive to further analysis and processing of data, such as data filtering, sorting and customized calculations.

3.1.2 Chinese Life Cycle Database

The Chinese Life Cycle Database (CLCD) was developed by the School of Architecture and Environment of Sichuan University and Yike Environmental Technology Co. Ltd. with the aim of providing localized life cycle environmental impact data support for Chinese products. The CLCD database covers the life cycle data of hundreds of bulk products in a variety of fields, such as energy, building materials, transportation, etc. The CLCD database includes energy consumption, greenhouse gas emissions, acidification, respirable inorganic substances, resource consumption and other environmental impact assessment indicators. The CLCD database covers the LCA data of hundreds of bulk products in various fields such as energy, building materials, transportation, etc., including energy consumption, GHG emission, acidification, respirable inorganic substances, resource consumption and other LCA indicators. These data originate from publicly released statistics and technical literature in China, providing a reliable data base for LCA and energy saving and emission reduction analysis of products in China.

It has been embedded into eBalance, a life cycle assessment (LCA) software developed by Yike Environmental Technology Co. Through eBalance; users can perform modelling, call up basic data, and complete boundary accounting for the environmental impacts of a building's life cycle. They can also generate assessment reports and ensure the transparency and traceability of data and research results.

In addition, the CLCD database provides sensitivity analysis and uncertainty measurement mechanisms, tools that help users conduct systematic and quantitative analysis and research on projects. Sensitivity analysis helps to identify which parameters have the greatest impact on the results, while uncertainty analysis can help to assess the reliability of the data.

- Volume of date

As a more mature life cycle basic database in China, its data volume is relatively rich, consisting of about 600 LCI datasets. It covers LCA data in a wide range of fields, such as bulk energy, raw materials and transportation in China. A large amount of basic data was collected in the early phases, and the amount of data continued to increase as the database developed and improved. For example, the field of energy may contain detailed data on various energy products, such as coal, oil, natural gas, etc., in different production links and transportation processes; in the field of raw materials, there are life cycle data of many kinds of basic raw materials, such as iron and steel, cement, plastics, non-ferrous metals, etc.; and in the field of transportation, it covers the data of different modes of transportation, such as road, railroad, waterway, air transport, etc., which are shown in Table 3-1.

trade	products of key projects
the sources of energy	Petroleum fuels: crude oil, diesel oil, gasoline, kerosene, etc Coal fuel: coal, coke, coke oven coal and so on Gas fuels: natural gas, liquefied petroleum gas, etc Power and steam: coal-fired thermal power, hydropower, power grid mixing, process steam, etc
ferrous metals	Iron ore, pellet / sinter, pig iron, ferrosilicon / ferrochrome and other ferroalloys, converter / electric furnace steel, etc
nonferrous metal	Copper concentrate, fire / wet method of electrolytic copper, bauxite, alumina, electrolytic aluminum, And lead, zinc, nickel, tin, antimony, mercury, magnesium, titanium, etc
inorganic nonmetal	Cement, concrete, limestone, gypsum, gravel, glass, ceramics, brick, etc
Inorganic chemicals	Inorganic raw materials: sulfuric acid, hydrochloric acid, nitric acid, sodium hydroxide, Soda ash, titanium dioxide, oxygen, nitrogen, synthetic ammonia, chlorine gas, etc
Organic chemicals	Ethylene, propylene, methanol, acetylene, resin, partial plastics, coatings, rubber, etc
transport	Road, rail, water transport
pollution abatement	Waste gas treatment: desulfurization, denitration
effluent disposal	Physical and chemical method, and the biochemical method

Table 3-1 Major Industries and Bulk Products Covered by the CLCD Database. Source: Xi'an University of Architecture and Technology

- Data format

Data Input Format: The input information format of the China Life Cycle Database (CLCD) may vary depending on the specific software or platform used, but in general, it includes the following: common information, basic information, production process information, transportation and logistics information, and waste treatment information.

Data Output Formats: According to the needs of users, a variety of data output formats are provided, such as Excel tables, CSV text files, XML files, etc. These formats can meet the needs of different users in data analysis, report writing, model construction and so on. At the same time, the database should also provide data visualization functions, complex data for charts, and other intuitive forms of display that are easy for users to understand and use.

Data Storage Format: A standardized data storage format is used to facilitate data management, query and use. Common data storage formats include relational database formats (e.g. MySQL, Oracle, etc.) or specialized LCA data storage formats (e.g. ILCD format, etc.). The relational database format allows for convenient data addition, deletion, modification and checking operations and is easy to interact with data from other systems; the ILCD format is the internationally recognized LCA data format, and its adoption allows for better compatibility and interfacing with international mainstream databases.

3.1.3 China Product Life Cycle Greenhouse Gas Emission Factor Set

The China Product Life Cycle GHG Emission Factor Set is a public dataset established and published by professional researchers of the China Urban GHG Working Group in 2021. It was established by the Carbon Peak Carbon Neutrality Research Center of the Academy of Environmental Planning of the Ministry of Ecology and Environment (MEP) in conjunction with 24 research institutions, including the Hangzhou International Science and Technology Center of Zhejiang

University. In addition, the China Urban GHG Working Group plays a coordinating role in it. The China Urban GHG Working Group is a voluntary organization that has gathered a large number of researchers to work voluntarily and pro bono since its establishment in 2017. Its basic methodology and principles were established mainly based on ISO 14067: 2018 Greenhouse gases-Carbon footprint of products-Requirements and guidelines for quantification. In addition, the data-set is reviewed by 16 authoritative experts for data quality assurance, so as to make the published data as scientific and standardized as possible. It provides an important basis for organizations, enterprises and individuals to accurately, quickly and uniformly calculate their carbon footprints and assess the carbon emissions of the whole life cycle of their products, which is of great significance to the management of GHG emissions from the consumption side and the promotion of carbon emission reduction based on the industrial chain, and can provide important data support for China to achieve the goal of carbon neutrality and carbon reaching the peak. The coefficient set is open online and dynamically updated, and colleges and universities, scientific research units, enterprises, individuals and various organizations are welcome to participate in its application, criticism and construction (real-name registration is sufficient), and this open mode is conducive to the continuous improvement and optimization of the data.

- Volume of date

This dataset's basic data are collected, analyzed, evaluated, and recalculated from the open literature. It covers seven major topics, including thousands of data on energy products, industrial products, household products, transportation services, waste, etc., and information on upstream and downstream emissions, GHG share, data timing, uncertainties, references/data sources, etc., are also presented.

- Data format

Data Input Format: The construction of this data set is based on the collection, compilation, analysis, evaluation and recalculation of open literature. The data input process will collect relevant information at different phases of the full life cycle of the product, such as information on GHG emissions at different phases of the production process, such as raw material acquisition, processing and manufacturing, as well as the use and waste disposal phases. This information comes from a variety of sources, such as research literature and industry reports, and must be organized and entered according to consistent standards and methodologies. For example, for energy products, the energy consumption and corresponding GHG emissions in the production process will be collected; for industrial products, emissions in the production process, transportation of raw materials, etc. will be considered.

Data output format: The data-set presents the output in a tabular format. The table contains several fields of information, such as product upstream emissions, downstream emissions, emission chain, GHG share, data time, uncertainty, references/data sources, etc. With this detailed information output, users can have a comprehensive understanding of each product's GHG emissions over its entire life cycle for accurate carbon footprint calculation and assessment. For example, in the output data of energy products, you can clearly see the value of upstream emissions during the production process of an energy product, the value of downstream emissions during the use process, as well as the proportion of different GHGs in the total emissions. The data-set is synchronized online and dynamically updated to provide users with easy access to the most up-to-date information. Users can access and use the data through a dedicated website (http://lca.cityghg.com/).

3.1.4 Ouroboros Software

This software is a comprehensive platform developed by Xi'an University of Architecture and Technology (XAUAT) that integrates “building life cycle carbon emission calculation”, “building carbon emission monitoring and accounting”, “building operation carbon emission monitoring and accounting”, “building product carbon footprint calculation” and “regional building cluster carbon emission monitoring”, “building product carbon footprint calculation” and “regional building group carbon emission monitoring”, such as Figure 3-1 shows the login interface of the platform.

In this platform, in addition to the necessary basic database, it also provides a platform for calculating carbon emission in the whole process of building, a platform for prediction of carbon emission in the preliminary phase, a platform for prediction of carbon emission in the design phase, a platform for calculation of carbon emission in BIM and a platform for monitoring of environment/ energy/carbon emission, as shown in Figure 3-2. The pre-process carbon emission prediction platform is mainly capable of predicting the carbon emission of the life cycle of a construction project and quantitatively evaluating the effectiveness of energy-saving and carbon-reducing technologies, which helps users to determine the positioning of the project, and to find the direction of low-carbon design and technological strategies.

Fig. 3-1 The login interface, source: Xi'an University of Architecture and Technology

建筑前期碳排放计算
适用于建筑设计前期，对建设项目生命周期碳排放预测，并定量评估节能降碳技术的有效性...

建筑方案碳排放计算
提供Revit插件，在线设置并计算建筑生命周期碳排放，并输出计算报告。

建筑施工图碳排放计算
在线录入建筑生命周期清单数据，计算建筑生命周期碳排放，并输出详细计算报告。

绿色建筑设计数据集
获取全球气候数据、提供气候分析和设计策略。旨在帮助设计师和分析师更好地理解和应...

建筑能耗模拟
获取全球气候数据、提供气候分析和设计策略。旨在帮助设计师和分析师更好地理解和应...

太阳能计算平台
基于全球气象数据模型的软件，能够提供高精度、实时的太阳能发电潜力查询。通过该平台...

©2021-2024 XUAUT 版权所有

Fig. 3-2 Functional display Interface, source: Xi'an University of Architecture and Technology

- Volume of date

Fig. 3-3 Database login interface, source: Xi'an University of Architecture and Technology

The building carbon emissions database will have another entry point; the login interface is shown in Figure 3-3, and the post-login interface is shown in Figure 3-4. The basic database covers a wide range of 13 categories (see Table 3-2 for details); specifically, the database covers the following key components: 1,450 types of carbon emission factors, divided into 22 energy, 11 raw materials, 16 building materials, 581 transportation, and 820 mechanical benches; over 2,000 types of building components with carbon emission factors; 924 building projects with 3E (environment, energy, and economy) cases; 592 building projects with 3E (environment, energy, and economy) cases; and 592 building projects with 3E (environment, energy, and economy) cases. Specifically, the database includes the following key components: 1450 types of carbon emission factors, divided into 22 types of energy, 11 types of raw materials, 581 types of building materials, 16 types of transportation, and 820 types of machinery; more than 2,000 types of carbon emission factors of building components; 924 3E (environment, energy, economy) cases of building projects; and 592 types of building materials with energy factors. This effectively solves one of the fundamental problems in the field of building carbon emission accounting - the serious lack of existing carbon emission factors.

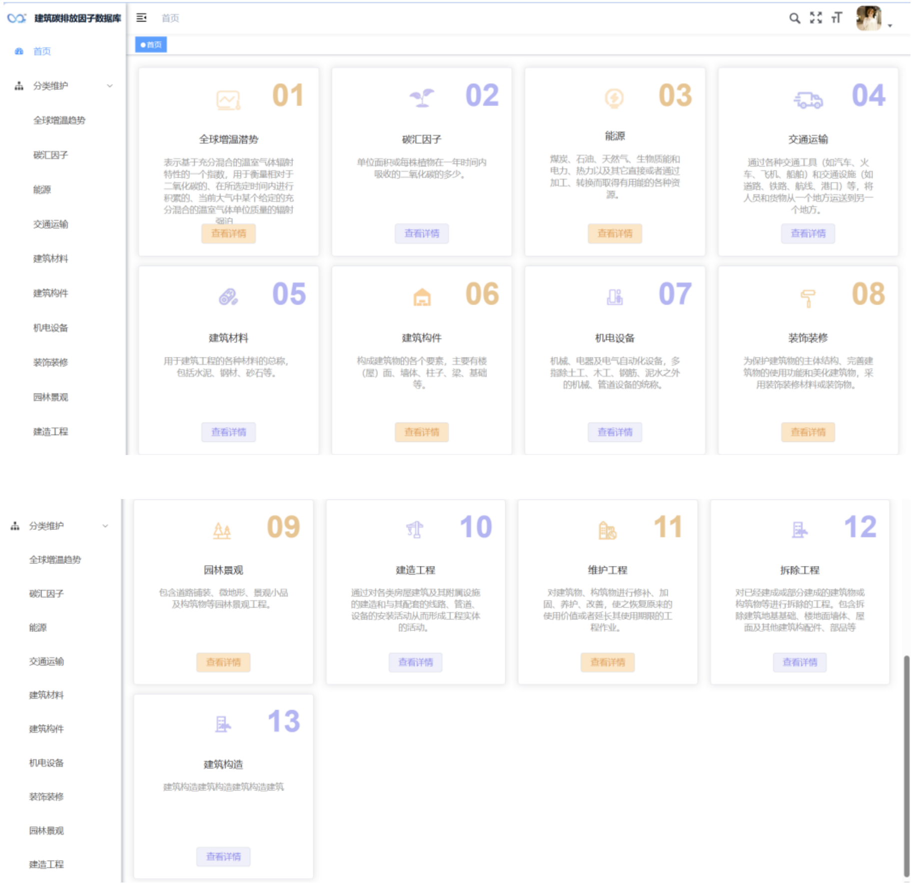


Fig. 3-4 Database display interface, source: Xi'an University of Architecture and Technology

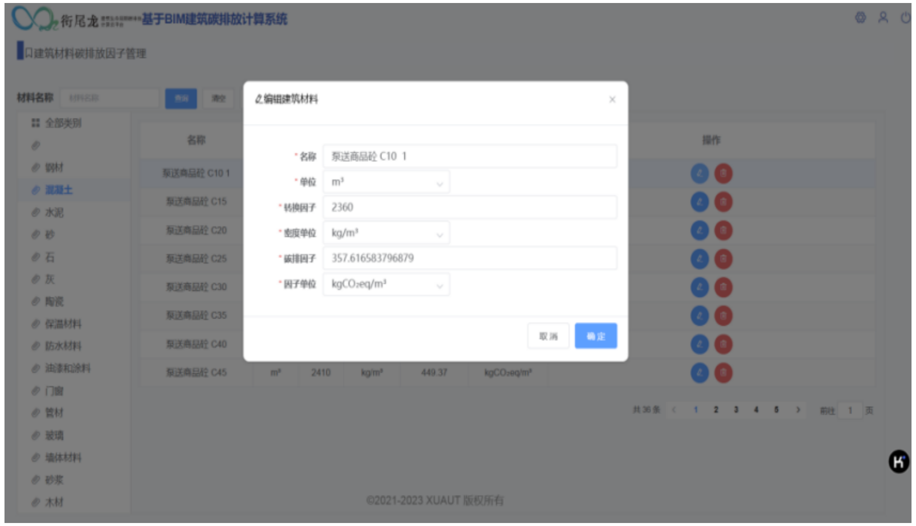
classify	primary coverage
Global warming potential	Represent an index based on the radiative properties of greenhouse gases, used to measure the radiation intensity of a given fully mixed greenhouse gas unit mass in the current atmosphere, relative to carbon dioxide, accumulated at the selected time period.
Carbon sink factor	per unit area or per plant over a year period of carbon dioxide.
the sources of energy	Coal, oil, natural gas, biomass energy and electricity, heat and other resources directly or through processing, conversion to obtain useful energy.
traffic	Various means of transportation (such as cars, trains, aircraft, ships) and transportation facilities (such as roads, railways, air routes, ports), etc.
Building material	Including cement, steel, sand and so on.
building unit	Various elements of the building, mainly building (house) surface, wall, pillars, beams, foundation and so on.
electromechanical equipment	Machinery, electrical appliances and electrical automation equipment, in addition to geotechnical, woodworking, steel, mud and water machinery, pipe equipment collectively.
Decoration	Protect the main structure of the building, improve the use function of the building and beautify the building, and use decoration materials or decorations.
Garden landscape	Including road pavement, micro-terrain, landscape sketch and structures and other landscape engineering.
Construction of the project	Through the construction of all kinds of housing buildings and their ancillary facilities and the installation of its supporting lines, pipelines and equipment, the engineering entity is formed.
Maintenance project	To repair, reinforce, maintain and improve buildings and structures so as to restore their original use value or extend their service life.
Demolition project	Works to demolish the buildings or structures that have been built or partially built. Including the demolition of the building foundation, floor wall, roof and other building components, parts, etc.
building construction	Including construction earthwork engineering, foundation treatment, measure projects and so on.

Table 3-2 Display interface of Carbon Emission Factor Manager, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

- Format of Data

In the design carbon emission prediction platform, people only need to enter the building life cycle inventory data online to calculate the building life cycle carbon emission and output a detailed calculation report, and the process is fully compliant with the “Standard for Building Carbon Emission Calculation” (GB/T 51366-2019) and the “General Specification for Energy Saving and Renewable Energy Utilization in Buildings” (GB 55015-2021); the BIM carbon emission calculation platform provides Revit plug-ins to set up and calculate building life cycle carbon emissions online and output calculation reports; in the environment/energy/carbon emission monitoring platform is able to monitor the indoor and outdoor physical environments of the building, operational energy consumption and carbon emissions in real-time, statistically analyze the monitoring data, and provide monitoring data on the big screen.

Compared with other databases, the platform has more detailed CEF data on building materials and more detailed data on different models of a certain material. As shown in Figure 3-5, the information displayed in the platform about the carbon emission factor of building materials mainly includes name, unit, conversion factor, density unit, carbon emission factor and factor unit. Regarding the unit setting, take concrete as an example, as shown in Figure 3-6, in which there are t, m^2, kg, m and thousands of units; according to the mainstream calculation method, m^3 is selected as the unit in the database, in fact, according to the different materials, the ranking of the calculation is convenient, and the unit displayed in the database will also be different.



编辑建筑材料

* 名称：泵送商品砼 C10 1

* 单位：m³

* 转换因子：2360

* 密度单位：kg/m³

* 碳排因子：357.616583796879

* 因子单位：kgCO₂eq/m³

泵送商品砼 C45	m³	2410	kg/m³	449.37	kgCO₂eq/m³

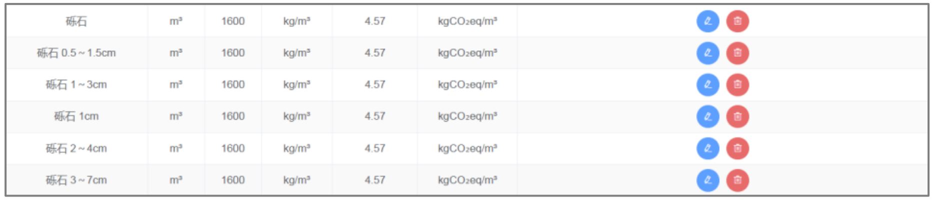
Fig. 3-5 Display interface of the carbon emission factor management side,source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

* 名称：泵送商品砼 C10 1

* 单位：m³

Fig. 3-6 Unit setting interface of carbon emission factor, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

In addition, there is also a large amount of integration of building materials of different types and sizes of a single type in the database. Taking gravel as an example, general data on gravel is provided in the database, and data on gravel of different sizes ranging from 0.5 to 7 cm are also provided, as shown in Figure 3-7. Overall, the platform's data in the construction field are more comprehensive, but of course there is still room for further improvement.

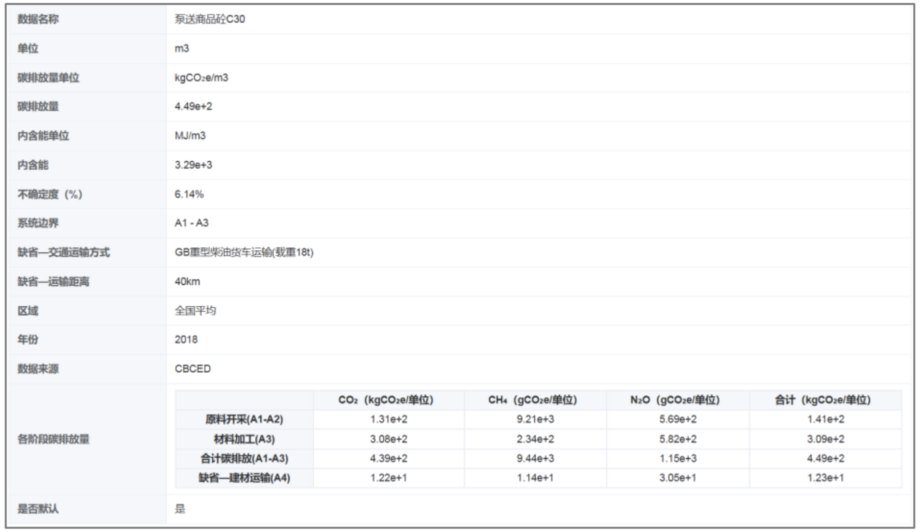


砾石	m³	1600	kg/m³	4.57	kgCO₂eq/m³
砾石 0.5～1.5cm	m³	1600	kg/m³	4.57	kgCO₂eq/m³
砾石 1～3cm	m³	1600	kg/m³	4.57	kgCO₂eq/m³
砾石 1cm	m³	1600	kg/m³	4.57	kgCO₂eq/m³
砾石 2～4cm	m³	1600	kg/m³	4.57	kgCO₂eq/m³
砾石 3～7cm	m³	1600	kg/m³	4.57	kgCO₂eq/m³

Fig. 3-7 Carbon Emission Factors for Different Gravel Sizes, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

Directly search in the database to view the carbon emission factor, the data of the Carbon Emission Factor in Ouroboros Database will be more detailed. As shown in the figure 3-8, it is the data interface of carbon emission factor of pumped commodity concrete C30, where the data is 449.368554 $\mathrm{kgCO_{2e}/m^3}$,and the accounting boundary is from A1-A3, indicating the size and type of the default value, as well as the data source.

In addition, the database also presents the carbon emissions of each phase in the form of a table, so that the user can more clearly read the value of the carbon emissions of the building materials in which the proportion of GHG is higher and the highest content of that phase. It also makes it easier for researchers working on materials production technologies to identify areas and issues where carbon reduction is needed.



<table>
<tr><td>数据名称</td><td>泵送商品砼C30</td></tr>
<tr><td>单位</td><td>m3</td></tr>
<tr><td>碳排放量单位</td><td>kgCO₂e/m3</td></tr>
<tr><td>碳排放量</td><td>4.49e+2</td></tr>
<tr><td>内含能单位</td><td>MJ/m3</td></tr>
<tr><td>内含能</td><td>3.29e+3</td></tr>
<tr><td>不确定度（%）</td><td>6.14%</td></tr>
<tr><td>系统边界</td><td>A1 - A3</td></tr>
<tr><td>缺省—交通运输方式</td><td>GB重型柴油货车运输(载重18t)</td></tr>
<tr><td>缺省—运输距离</td><td>40km</td></tr>
<tr><td>区域</td><td>全国平均</td></tr>
<tr><td>年份</td><td>2018</td></tr>
<tr><td>数据来源</td><td>CBCED</td></tr>
<tr><td>各阶段碳排放量</td><td><table>
<tr><th></th><th>CO₂（kgCO₂e/单位）</th><th>CH₄（gCO₂e/单位）</th><th>N₂O（gCO₂e/单位）</th><th>合计（kgCO₂e/单位）</th></tr>
<tr><th>原料开采(A1-A2)</th><td>1.31e+2</td><td>9.21e+3</td><td>5.69e+2</td><td>1.41e+2</td></tr>
<tr><th>材料加工(A3)</th><td>3.08e+2</td><td>2.34e+2</td><td>5.82e+2</td><td>3.09e+2</td></tr>
<tr><th>合计碳排放(A1-A3)</th><td>4.39e+2</td><td>9.44e+3</td><td>1.15e+3</td><td>4.49e+2</td></tr>
<tr><th>缺省—建材运输(A4)</th><td>1.22e+1</td><td>1.14e+1</td><td>3.05e+1</td><td>1.23e+1</td></tr>
</table></td></tr>
<tr><td>是否默认</td><td>是</td></tr>
</table>

Fig 3-8 The carbon emission factor of pumped commercial concrete C30 in the Ouroboros database, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

3.2 Comparison of databases

3.2.1 Comparison of calculation methods

The following table3-3 discusses the methodology for calculating carbon emissions for each database by building life cycle phases

software	Materials production and transportation phase	Operation phase	Construction and demolition phase
Donghe	1.Enter information on energy and resource consumption and waste emissions from the production and transportation of building materials according to the template. 2.Calculate carbon emissions in the production phase based on the built-in carbon emission factors and information on building materials, and calculate carbon emissions in the transportation phase based on the amount of building materials consumed, transportation distance, mode of transportation and the corresponding carbon emission factors.	1.Collect all types of energy consumption in the operation of the building. 2.Calculate carbon emissions in combi- nation with energy carbon emission factors, taking into account carbon reduction from re- newable energy sources and carbon sink systems.	1. Construction phase: Calculated based on construction energy consumption and carbon emission factors. 2. Dismantling phase: Calculated on the basis of energy consumption for dismantling and carbon emission factor, and energy consumption is determined according to the dismantling program.
CLCD	1.Production phase: Determine the carbon emission factor for building materials using industry statistics and literature data, and calculate it in conjunction with the amount of building materials used in the project. 2.Transportation phase: Calculated on the basis of transportation mode, distance and carbon emission factor.	1.Analyze the energy consumption data of each equipment and system in operation. 2.Calculate carbon emissions during the operation phase in combination with energy carbon emission factors.	1.Determine carbon emission factors based on mechanical equipment, energy consumption and processes used for construction and demolition. 2.Calculate carbon emissions in conjunction with actual equipment types, working hours and energy consumption.
CPCD	1. Production phase: collect industry data to determine the GHG emission factor for building materials and calculate it in conjunction with the amount of building materials used in the project. 2.Transportation phase: Determine the emission factor based on transportation factors and calculate it with transportation information.	1.Analyze energy use in operation, e.g., electricity, gas, etc. 2.Calculate GHG emissions based on energy consumption and emission factors, taking into account the function and duration of use.	1. Construction phase: Analyze the emission factor of the construction process and calculate the GHG emissions by combining the construction information. 2.Dismantling phase: Calculate based on dismantling operations and resource consumption.
Ourobor os Software	1.Collect building materials production data to build a model, and calculate carbon emissions in the production phase after the user inputs parameters.	1.Interfacing with energy monitoring systems to obtain energy consumption data.	1.Construction phase: Break down the construction process, analyze the energy consumption of each activity and calculate

	2.Determine the calculation method by considering the transportation factor, and calculate the carbon emissions in the transportation phase by combining the input transportation information.	2.Calculate emissions based on energy consumption and carbon emission factors, analyze energy use efficiency and provide recommendations.	carbon emissions. 2.Dismantling phase: Evaluate the equipment, energy and waste disposal aspects of the dismantling process to calculate emissions.

Table 3-3 Carbon Emission Calculation Methods for 4 Databases, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

3.2.2 Comparison of specific applications

In the previous section, each platform has been introduced through detailed text, in order to reflect the convenience and accuracy of each platform in the process of using it in a more intuitive way, the following will take concrete, a common building material, as an example, and will focus on the corresponding content of the above database (Table 3-4).

Software	**Data presentation page**
Donghe	
CLCD	

建材生产阶段碳排放

序号	主要工料	主要工料类别	主要工料消耗指标	单位	碳排放因子	因子单位
1	商品砼	C30混凝土	0.5	m3/m2	295	kgCO2e/m3
2	商品砼	C50混凝土	0	m3/m2	385	kgCO2e/m3
3	商品砼	C60混凝土	0	m3/m2	398.64	kgCO2e/m3
4	商品砼	C70混凝土	0	m3/m2	448.84	kgCO2e/m3
5	钢材	热轧碳钢钢筋	55	kg/m2	2340	kgCO2e/t

自资料调查-代表典型水平，中国2016:5.04%	熟料煅烧
全国电网电力（到用户）kWh，其他，从摇篮到大门 (从资源开采到产品出厂)，来自资料调查-代表典型水平，中国2021:4.85%	熟料煅烧 更新版碎石 51366-C30混凝土 -
洗精煤（运输后）t，未分类，从摇篮到大门 (从资源开采到产品出厂)，来自资料调查-代表典型水平，2020:1.08%	熟料煅烧
柴油（炼油厂平均）(t，未分类)，从摇篮到大门 (从资源开采到产品出厂)，来自资料调查-代表技术平均，中国2015:0.86%	-
柴油（市场平均）t，未分类，从摇篮到大门 (从资源开采到产品出厂)，来自资料调查-代表典型水平，中国2020:0.06%	-

完整性说明

cut-off规则	1.普通物料重量＜1%产品重量时，以及含稀 2.低价值废物作为原料，如粉煤灰、矿渣、秸 3.大多数情况下，生产设备、厂房、生活设施 4.在选定环境影响类型范围内的已知排放数据

cut-off详情：符合取舍规则,总忽略物料重量占比为0.00360966076485829

上游数据完整性

#	过程名称	消耗名称
1	51366-C30混凝土	粉煤灰

LCIA多指标结果

当前数据的来源信息为:

数据集来源：中国生命周期基础数据库CLCD，成都亿科环境科技有限公司

数据集名称：51366-C30混凝土（m3），从摇篮到大门（水泥添加300~400kg/m³，普通拌和；干法普通硅酸盐水泥-熟料70%-80%+石膏+混合材，开路粉磨；），研究型系列数据集，来自资料表典型水平，中国2022

数据集文档和模型链接：https://www.efootprint.net/baseModel?code=a2Eh1ms

查看数据集手机端文档

指标名称	结果	单位
一次能源消耗	2.43	MJ
非生物资源消耗潜值	2.20	kg antimony eq.
水资源消耗	1.17	kg
酸化	7.87	kg SO2 eq
富营养化潜值	1.27	kg PO43-eq
可吸入无机物	2.94	kg PM2.5 eq
臭氧层消耗	1.00	kg CFC-11 eq

CPCD

中国产品全生命周期温室气体排放系数库
CPCD, China Products Carbon Footprint Factors Database

共29个产品碳足迹数据，涉及19家企业

产品ID	产品名称/型号	核算边界	碳足迹/功能单元	数据时间	
37540X0232019C	C30混凝土	摇篮到大门	295kgCO2e / 吨	2019	查看 | 加入对比
37560X0112023C	C40普通混凝土	摇篮到大门	321.8kgCO2e / 立方米	2023	查看 | 加入对比
37550X0042019C	C50混凝土	摇篮到大门	385kgCO2e / 吨	2019	查看 | 加入对比
37540X0022015A	加气混凝土	摇篮到坟墓	1369.35kgCO2e / 立方米	2015	查看 | 加入对比
37540X0012021A	混凝土	摇篮到大门	1331.76kgCO2e / 吨	2021	查看 | 加入对比
37540X0252018B	混凝土	摇篮到大门	455.87kgCO2e / 立方米	2018	查看 | 加入对比

生命周期各阶段碳足迹（单位：kgCO2e）

Ouroboros Software

名称	单位	碳排放因子（kgCO_2e/单位）	年份	区域	来源	系统边界
泵送商品砼C10	m3	3.58e+2	2018	全国平均	CBCED	A1 - A3
泵送商品砼C15	m3	3.70e+2	2018	全国平均	CBCED	A1 - A3
泵送商品砼C20	m3	4.37e+2	2018	全国平均	CBCED	A1 - A3
泵送商品砼C25	m3	4.49e+2	2018	全国平均	CBCED	A1 - A3
泵送商品砼C30	m3	4.49e+2	2018	全国平均	CBCED	A1 - A3

数据名称	C30混凝土
单位	m3
碳排放量单位	kgCO_2e/m3
碳排放量	2.95e+2
内含能单位	MJ/m3
内含能	
不确定度（%）	3.87%
系统边界	A1 - A3
缺省—交通运输方式	GB重型柴油货车运输(载重18t)
缺省—运输距离	40km
区域	全国平均
年份	2019
数据来源	GB/T 51366
各阶段碳排放量	
是否默认	是

各阶段碳排放量

	CO_2（kgCO_2e/单位）	CH_4（gCO_2e/单位）	N_2O（gCO_2e/单位）	合计（kgCO_2
原料开采(A1-A2)				
材料加工(A3)				
合计碳排放(A1-A3)				2.95e+
缺省—建材运输(A4)	0.00e+0	0.00e+0	0.00e+0	0.00e+

Table 3-4 Concrete Carbon Emission Factor Data for Four Databases, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

By comparing several databases, it can be found that the carbon emission factor values for C30 concrete do not differ much overall across platforms, but there are slight differences in units. Donghe is $295\mathrm{kgCO}_{2e}/\mathrm{m}^3$, CLCD can't find the specific data intuitively, CPCD is $295\mathrm{kgCO}_{2e}/\mathrm{m}^3$, and the value is also $295\mathrm{kgCO}_{2e}/\mathrm{m}^3$.

In a comprehensive comparison, the data in Donghe and Ouroboros is more intuitive, and the display interface of the two will be more systematic, and the classification is relatively clearer; as for the details of the calculation of the carbon emission factor, according to the comparison of the public interface, the CLCD, CPCD and Ouroboros are all embodied, and the display of the organizational composition and the display of the technological level of the CLCD are the most detailed, but there is a lack of data completeness in the computer display interface.

Incomplete data. In terms of simplicity of operation and intuitive practicality of the data, the Ouroboros is superior.

3.2.3 Comprehensive Comparison

In terms of building materials carbon emission factor database establishment, each database has its own advantages and disadvantages, which will be analyzed in the following.

The first one is Donghe Software, which has the problem that the data coverage may be limited: it mainly focuses on the calculation of carbon emission in the building field, and the coverage of carbon emission factors of some special building materials or new building materials may not be comprehensive enough, and there may be insufficient data when facing some cutting-edge building projects. Compared with other software, there is a lack of user participation in co-construction, and the data updating and improvement of the software mainly rely on the R&D team, with relatively low user participation, which may lead to some problems or special situations found in practical applications not being able to be fed back into the database in time, affecting the real-time and accuracy of the data.

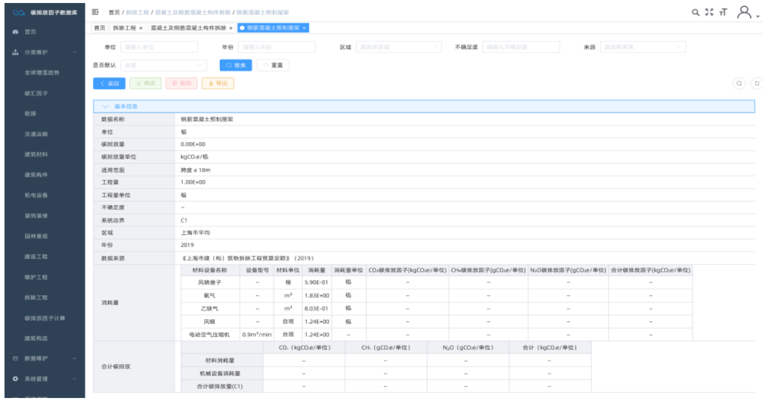
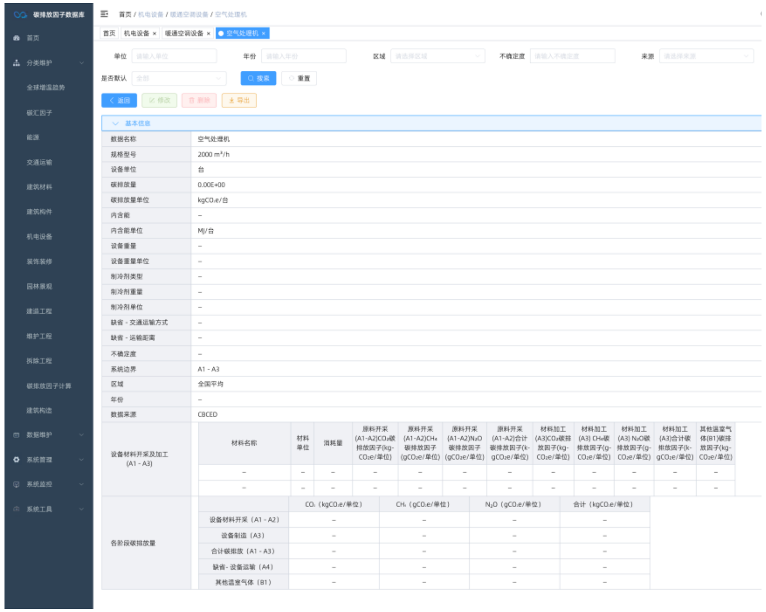
Next is the CLCD database, which also suffers from the problem of possible lag in data updating. Although the data have been evaluated, with the continuous development of the construction industry and the continuous progress of technology, the production process and energy consumption of building materials may change, and the data updating speed of the database may not be able to keep up with the development of the industry, resulting in the lack of timeliness of some of the data. Secondly, the database mainly provides general carbon emission factor data for building materials, and may not be able to provide personalized carbon emission factor customization services for some special projects or users with special requirements, which limits the flexibility of its application to a certain extent.

The CPCD database is more inclined to provide data support for basic carbon emission factors for various industries and fields in China, emphasizing more on “breadth”, which results in the coverage of carbon emission factors for building carbon emission factors is still relatively small, and the functional units used for some materials are difficult to be applied to the actual construction works of buildings, and the functional units used are “kg” which is different from “m^3” commonly used in actual construction works. The functional unit used for some materials is not applicable to actual building construction projects, and its functional unit is “kg”, which is different from the “m^3” commonly used in actual construction projects, thus the applicability of the study on building carbon emission needs to be improved and updated. In addition, as a database established by a voluntary organization, even though it has been evaluated by experts, there is still a gap between the authority and recognition of the data and that of the database established by official or professional organizations, and it may need to be further verified and validated in some projects with higher data requirements.

As for the Ouroboros, as a relatively new software, the construction of its database is still in the process of continuous improvement, but in terms of the database of carbon emission factors of building materials, the data it gives are more detailed, and the interface design is more unified, and it is relatively easier to obtain the data of a single building material after its breakdown. The database emphasizes the integration of calculation and monitoring of building carbon emission, and is able to obtain real-time carbon emission data of building projects, and dynamically adjust and optimize the carbon emission factors of building materials according to the monitoring results, so as to make the data more in line with the actual situation. As for the amount of data, the developers will also work with experts in materials science to verify the data again in the near future, in an effort to conform to reality.

3.3 Case Study - Ouroboros Software

The creation of the database for the Ouroboros Software marks the realization of a number of innovations and breakthroughs, which greatly enriches the data resources by incorporating more than 1,100 additional factors on top of the national standard data.The following will show the interface of the carbon emission factor database.

Type	Database Interface
dismantling	
Electromechanical equipment	 

数据名称	钢筋混凝土预制屋架
单位	榀
碳排放量	0.00E+00
碳排放量单位	kgCO₂e/榀
适用范围	跨度 ≤ 18m
工程量	1.00E+00
工程量单位	榀
不确定度	–
系统边界	C1
区域	上海市平均
年份	2019
数据来源	《上海市建（构）筑物拆除工程预算定额》（2019）

消耗量

材料设备名称	设备型号	材料单位	消耗量	消耗量单位	CO₂碳排放因子(kgCO₂e/单位)	CH₄碳排放因子(gCO₂e/单位)	N₂O碳排放因子(gCO₂e/单位)	合计碳排放因子(kgCO₂e/单位)
风镐凿子	–	根	5.90E-01	榀	–	–	–	–
氧气	–	m³	1.83E+00	榀	–	–	–	–
乙炔气	–	m³	8.03E-01	榀	–	–	–	–
风镐	–	台班	1.24E+00	榀	–	–	–	–
电动空气压缩机	0.9m³/min	台班	1.24E+00	–	–	–	–	–

合计碳排放

	CO₂（kgCO₂e/单位）	CH₄（gCO₂e/单位）	N₂O（gCO₂e/单位）	合计（kgCO₂e/单位）
材料消耗量	–	–	–	–
机械设备消耗量	–	–	–	–
合计碳排放量(C1)	–	–	–	–

名称	规格型号	碳排放因子（kgCO₂e/单位）	年份	区域	来源	不确定度	系统边界
▾ 机电设备							
▾ 暖通空调设备							
空气处理机	2000 m³/h	–	–	全国平均	CBCED	–	A1 - A3
空气处理机	3700 m³/h	–	–	全国平均	CBCED	–	A1 - A3
中央空气处理机	10m³/h	–	–	全国平均	CBCED	–	A1 - A3
中央空气处理机	30m³/h	–	–	全国平均	CBCED	–	A1 - A3
普通空气处理机	–	–	–	全国平均	CBCED	–	A1 - A3
普通空气处理机 热交换板	–	–	–	全国平均	CBCED	–	A1 - A3
普通空气处理机 热交换旋转器	–	–	–	全国平均	CBCED	–	A1 - A3
小型空气处理机	–	–	–	全国平均	CBCED	–	A1 - A3
小型空气处理机 热交换板	–	–	–	全国平均	CBCED	–	A1 - A3
小型空气处理机 热交换旋转器	–	–	–	全国平均	CBCED	–	A1 - A3
压缩锅炉	100 kW	–	–	全国平均	CBCED	–	A1 - A3
压缩锅炉	120 kW	–	–	全国平均	CBCED	–	A1 - A3
压缩锅炉	120 - 140 kW	–	–	全国平均	CBCED	–	A1 - A3
轴承离心式冷水机	–	–	–	全国平均	CBCED	–	A1 - A3
电动热泵空气-水	10 kW	–	–	全国平均	CBCED	–	A1 - A3

数据名称	空气处理机
规格型号	2000 m³/h
设备单位	台
碳排放量	0.00E+00
碳排放量单位	kgCO₂e/台
内含能	–
内含能单位	MJ/台
设备重量	–
设备重量单位	–
制冷剂类型	–
制冷剂重量	–
制冷剂单位	–
缺省 - 交通运输方式	–
缺省 - 运输距离	–
不确定度	–
系统边界	A1 - A3
区域	全国平均
年份	–
数据来源	CBCED

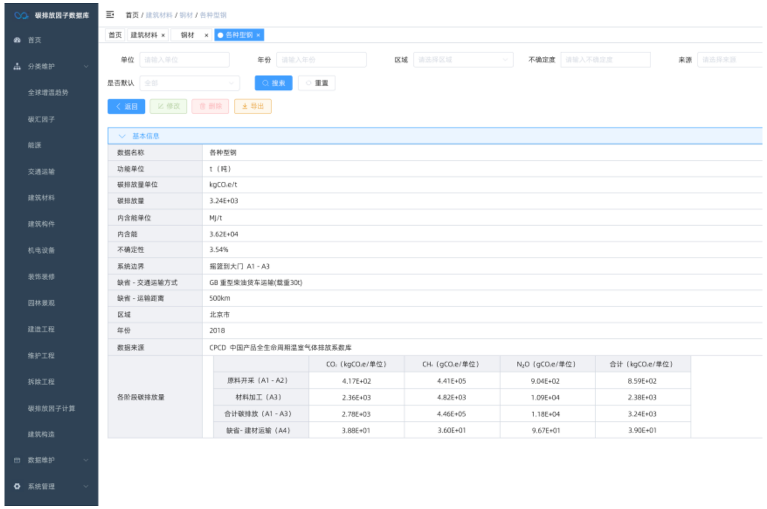
设备材料开采及加工 (A1 - A3)

材料名称	材料单位	消耗量	原料开采 (A1-A2)CO₂碳排放因子(kg-CO₂e/单位)	原料开采 (A1-A2)CH₄碳排放因子 (gCO₂e/单位)	原料开采 (A1-A2)N₂O碳排放因子 (gCO₂e/单位)	原料开采 (A1-A2)合计碳排放因子(k-gCO₂e/单位)	材料加工 (A3)CO₂碳排放因子(kg-CO₂e/单位)	材料加工 (A3) CH₄碳排放因子(g-CO₂e/单位)	材料加工 (A3) N₂O碳排放因子(g-CO₂e/单位)	材料加工 (A3)合计碳排放因子(k-gCO₂e/单位)	其他温室气体(B1)碳排放因子(kg-CO₂e/单位)
–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–

各阶段碳排放量

	CO₂（kgCO₂e/单位）	CH₄（gCO₂e/单位）	N₂O（gCO₂e/单位）	合计（kgCO₂e/单位）
设备材料开采（A1 - A2）	–	–	–	–
设备制造（A3）	–	–	–	–
合计碳排放（A1 - A3）	–	–	–	–
缺省 - 设备运输（A4）	–	–	–	–
其他温室气体（B1）	–	–	–	–

building material



数据名称	各种型钢
功能单位	t（吨）
碳排放量单位	kgCO$_2$e/t
碳排放量	3.24E+03
内含能单位	MJ/t
内含能	3.62E+04
不确定性	3.54%
系统边界	摇篮到大门 A1 - A3
缺省 - 交通运输方式	GB 重型柴油货车运输(载重30t)
缺省 - 运输距离	500km
区域	北京市
年份	2018
数据来源	CPCD 中国产品全生命周期温室气体排放系数库

各阶段碳排放量

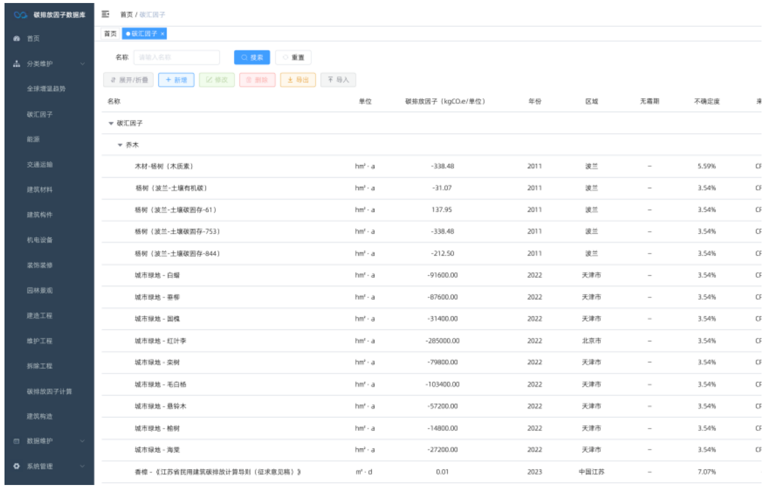
	CO$_2$（kgCO$_2$e/单位）	CH$_4$（gCO$_2$e/单位）	N$_2$O（gCO$_2$e/单位）	合计（kgCO$_2$e/单位）
原料开采（A1 - A2）	4.17E+02	4.41E+05	9.04E+02	8.59E+02
材料加工（A3）	2.36E+03	4.82E+03	1.09E+04	2.38E+03
合计碳排放（A1 - A3）	2.78E+03	4.46E+05	1.18E+04	3.24E+03
缺省- 建材运输（A4）	3.88E+01	3.60E+01	9.67E+01	3.90E+01

Building components

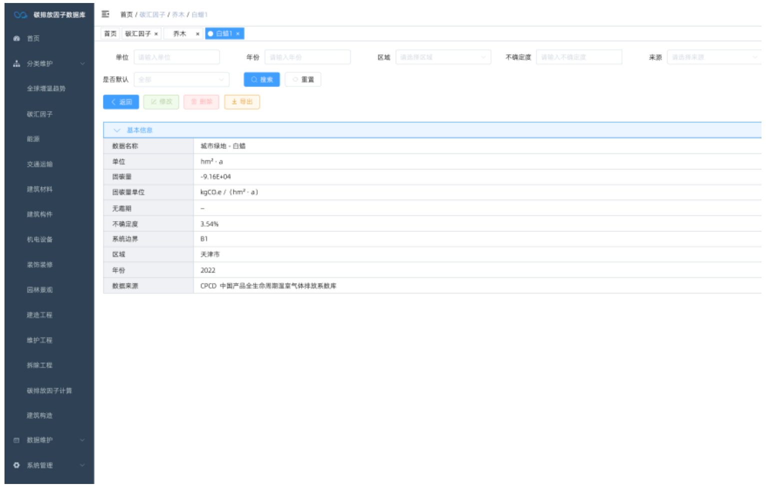
名称	单位	碳排放因子（kgCO$_2$e/单位）	年份	区域	来源	不确定度
▾ 建筑构件						
▾ 台阶						
混凝土台阶	m^2	173.00	2022	陕西省平均	CBCED	–
水泥砂浆面层台阶	m^2	186.00	2022	陕西省平均	CBCED	–
地砖面层台阶	m^2	187.00	2022	陕西省平均	CBCED	–
剁斧石面层台阶	m^2	191.00	2022	陕西省平均	CBCED	–
花岗石板面层台阶	m^2	192.00	2022	陕西省平均	CBCED	–
条石台阶	m^2	220.00	2022	陕西省平均	CBCED	–
▸ 坡道						
▸ 散水						
▸ 防潮层						
▸ 外墙饰面						
▸ 地面						
▸ 楼面						
▸ 踢脚						
▸ 内墙饰面						
▸ 屋面						

carbon

sink factor



名称	单位	碳排放因子（kgCO$_2$e/单位）	年份	区域	无霜期	不确定度
▾ 碳汇因子						
▾ 乔木						
木材-杨树（木质素）	hm^2 · a	-338.48	2011	波兰	–	5.59%
杨树（波兰-土壤有机碳）	hm^2 · a	-31.07	2011	波兰	–	3.54%
杨树（波兰-土壤碳固存-61）	hm^2 · a	137.95	2011	波兰	–	3.54%
杨树（波兰-土壤碳固存-753）	hm^2 · a	-338.48	2011	波兰	–	3.54%
杨树（波兰-土壤碳固存-844）	hm^2 · a	-212.50	2011	波兰	–	3.54%
城市绿地 - 白蜡	hm^2 · a	-91600.00	2022	天津市	–	3.54%
城市绿地 - 垂柳	hm^2 · a	-87600.00	2022	天津市	–	3.54%
城市绿地 - 国槐	hm^2 · a	-31400.00	2022	天津市	–	3.54%
城市绿地 - 红叶李	hm^2 · a	-285000.00	2022	北京市	–	3.54%
城市绿地 - 栾树	hm^2 · a	-79800.00	2022	天津市	–	3.54%
城市绿地 - 毛白杨	hm^2 · a	-103400.00	2022	天津市	–	3.54%
城市绿地 - 悬铃木	hm^2 · a	-57200.00	2022	天津市	–	3.54%
城市绿地 - 榆树	hm^2 · a	-14800.00	2022	天津市	–	3.54%
城市绿地 - 海棠	hm^2 · a	-27200.00	2022	天津市	–	3.54%
香樟 - 《江苏省民用建筑碳排放计算导则（征求意见稿）》	m^2 · d	0.01	2023	中国江苏	–	7.07%



数据名称	城市绿地 - 白蜡
单位	hm^2 · a
固碳量	-9.16E+04
固碳量单位	kgCO$_2$e /（hm^2 · a）
无霜期	–
不确定度	3.54%
系统边界	B1
区域	天津市
年份	2022
数据来源	CPCD 中国产品全生命周期温室气体排放系数库

Table 3-5 Database Interface for Selected Carbon Emission Factor Data, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

3.3.1 Introduction of function module

The establishment of this software enables users to conveniently and standardized query and call all kinds of building carbon emission factors and to freely combine and calculate the carbon emission factors of building materials and components according to their actual needs. At the same time, there is an editing function for platform administrators to constantly update and improve the relevant data so as to make the building carbon emission factors as targeted as possible to be applied in actual construction cases and to realize the scientific research on building carbon emission and carbon reduction. The database should mainly contain the following functional modules.

- Data import and export

The system can automatically search for files in ".xlsx" or ".xls" format, such as energy carbon emission factor, transportation carbon emission factor, building material carbon emission factor, etc., from the user-specified folder, and import the data in the Excel table file into the database platform. The data in the Excel table file will be imported into the database platform. Meanwhile, users can also export the data to Excel table files according to their personal needs.

- Data editing and query call

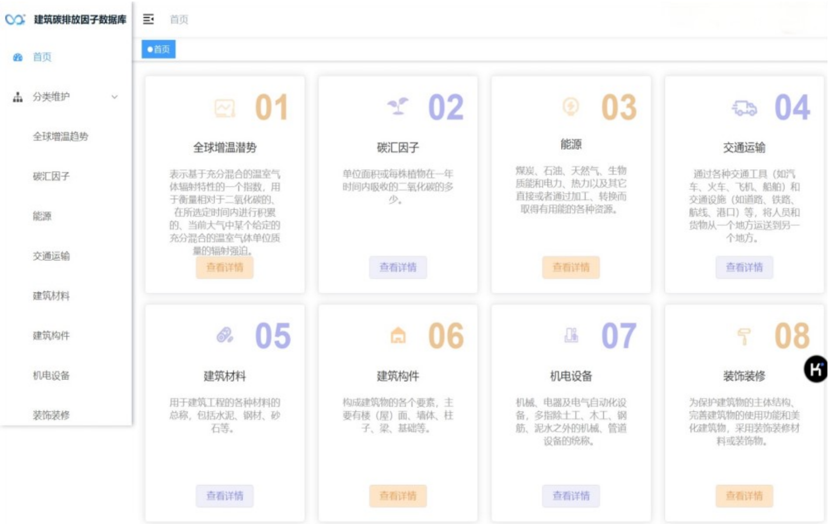
The data query calling function board enables users to search and use the building carbon emission factors according to their personal needs and realize the search and browsing of energy, building materials and other carbon emission factor forms, such as the value of the carbon emission factor data, the year, the source of the data and uncertainty and other related information. At the same time, the carbon emission factor value, year, source and other content can be based on the data editing function, customised to submit applications for adding, modifying or deleting, fill in the relevant data by the site management personnel for background review and publicity, and thus provide a good guarantee for the scientific nature and applicability of the database.

- Data combination calculation

The online database platform is designed with a "Carbon Emission Factor Calculation" section, which can realize the independent combination calculation of carbon emission factors of building materials and components. For building carbon emission factors that are missing in the database or mismatched in terms of project usage and construction practices, users can arrange and combine the basic building carbon emission factors according to their personal needs and the corresponding actual project practices based on the methodological rules established in the previous section, so as to combine the "production of building materials", "transportation of building materials", "transportation of building materials" and "transportation of building materials" into one. Transportation of building materials" 'Construction and installation' 'Building maintenance' 'Building renewal' "Building demolition ", and "Recycling and reuse" phases are combined and calculated to obtain building carbon emission data that meets the needs of actual construction projects.

3.3.2 The process of usage

After completing the registration, users can log in to the database online platform with their accounts and passwords. The main interface of the database is mainly divided into two main parts, as shown in Figure 3-9, the right part is the corresponding big data module of the database, i.e. GWP, carbon sink factor, etc.; the left side is the navigation bar of the corresponding module and the subordinate boards, which is convenient for the users to click on the corresponding columns for a quick transfer to the interface, which contains the function module of “Calculation of Carbon Emission Factor” that realizes the independent needs of the users. There is a functional module “Carbon Emission Factor Calculation” which can realize the user's independent demand, and after clicking it, the user can jump to the corresponding secondary interface.



01 全球增温潜势

表示基于充分混合的温室气体辐射特性的一个指数，用于衡量相对于二氧化碳的、在所选定时间内进行积累的、当前大气中某个给定的充分混合的温室气体单位质量的辐射强迫。

02 碳汇因子

单位面积或每株植物在一年时间内吸收的二氧化碳的多少。

03 能源

煤炭、石油、天然气、生物质能和电力、热力以及其它直接或者通过加工、转换而取得有用能的各种资源。

04 交通运输

通过各种交通工具（如汽车、火车、飞机、船舶）和交通设施（如道路、铁路、航线、港口）等，将人员和货物从一个地方运送到另一个地方。

05 建筑材料

用于建筑工程的各种材料的总称，包括水泥、钢材、砂石等。

06 建筑构件

构成建筑物的各个要素，主要有楼（屋）面、墙体、柱子、梁、基础等。

07 机电设备

机械、电器及电气自动化设备，多指除土工、木工、钢筋、泥水之外的机械、管道设备的统称。

08 装饰装修

为保护建筑物的主体结构、完善建筑物的使用功能和美化建筑物，采用装饰装修材料或装饰物。

Fig. 3-9 Home screen after registering and logging in, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

- Enter basic information of project

The core of the “Carbon Emission Factor Calculation” function is the flexible combination and calculation of building carbon emission factors. When the database lacks or is difficult to adapt to the building carbon emission factors required by the user, the user can freely combine and calculate the carbon emissions from the production of building materials, the transportation of building materials, the construction and the installation of building materials according to their wishes, and then obtain the required values, which can be flexibly applied to the research of each project.

When users need to calculate the carbon emission of a certain building material or component, they can click “New Product” in the upper right corner of the interface, and in the pop-up information box, enter “Product Name”, “Functional Unit”, “Data Source”, “Functionality”, “Functionality”, “Functionality”, “Functionality”, “Functionality”, “Functionality” and “Functionality”. In the pop-up information box, fill in the basic information such as “product name”, “functional unit”, “data source”, “data representativeness”, etc., and select “production of building materials”, “transportation of building materials”, “transportation of building materials”, etc. “Building materials production” and ‘building materials transportation’ and other calculation phases to ensure the standardization and rationalization of carbon emission calculation. At the same time, there is a “data-description” at the bottom of the fill-in box, which allows users to further explain and illustrate the data, as shown in Figure 3-10.

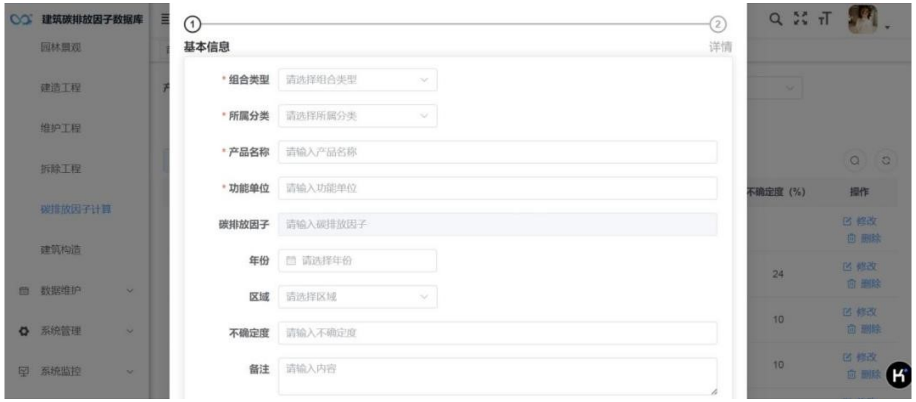


Fig. 3-10 New Product Information Filling Interface, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

- Modeling calculation

After filling in the basic calculation information of the building product, you can click "Next, Modeling and Calculation" to jump to the formal calculation interface, such as Figure 3-11, where users can fill in the information of energy, materials and emissions at various phases of the production process of the building product by clicking "Add Input" or "Add Output" button. In this interface, users can click "Add Input" or "Add Output" button to fill in the information of energy, material and emission in each phase of the production process of the building product.

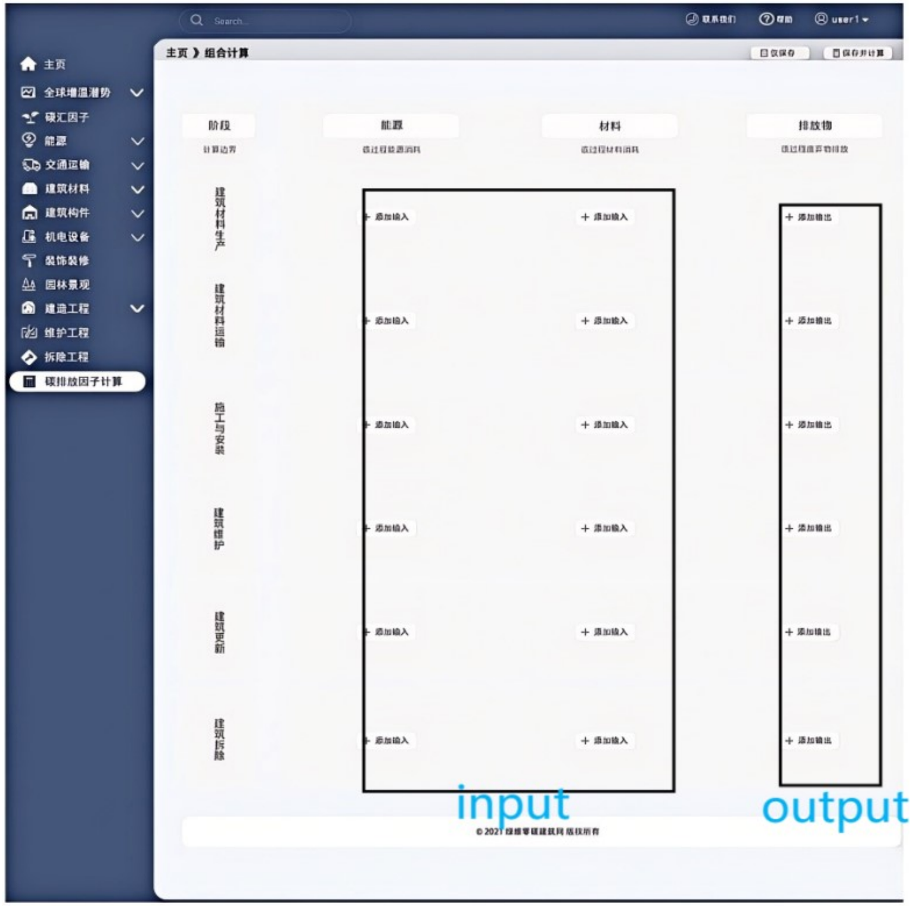


Fig.3-11 Fill in the interface of each information selection, source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

- Database tertiary interface

In the process of using the software, the main display of the first and second level interface, there is also a third level interface in this software. Taking the energy carbon emission factor as an example, the third-level interface displays the specific information of this category of carbon emission factor, including the name of the carbon emission factor, unit, year, region, carbon oxidation rate, uncertainty, data source information, carbon emissions from raw material extraction phase, carbon emissions from combustion phase, total carbon emissions, and the contribution of carbon emissions of CO_2, CH_4, and NO_2 under the respective phases, which can be used by the user for comparison. as shown in Figure 3-12.

Meanwhile, in the three-level interface of each carbon emission factor dataset, “New”, “Import”, “Export”, “Edit” functions are set up for different user groups to facilitate the use of each function by users with different privileges. The function of “New”, “Import”, “Export” and “Edit” is set for different user groups to facilitate the use of each function by users with different privileges, after clicking “New”, users can fill in the data at the bottom of the interface table; after clicking “Import”, users can batch export relevant files in Execl format; after clicking “Export”, users can multi-select data for batch export; click “Edit”, you can enter the editing mode, and then directly modify and improve the data, as shown in Figure 3-13.

能源-煤炭及煤制品碳排放因子

序号	名称	单位	原材料开采（kgCO₂e/单位）				燃烧（kgCO₂e/单位）				合计碳排放（kgCO₂e/单位）				年份	区域	碳氧化率（%）	不确定度（%）	来源
			CO₂	CH₄	NO₂	合计	CO₂	CH₄	NO₂	合计	CO₂	CH₄	NO₂	合计					
1	原煤	kg	0.09	0.26	0.00	0.35	1.98	0.01	0.01	2.00	2.07	0.27	0.01	2.35	2018	全国平均	96		CBCED
2	标准煤	kg	—	—	—	—	2.77	0.01	0.01	2.79	2.77	0.01	0.01	2.79	2018	全国平均	98		
3	无烟煤	GJ	—	—	—	—	—	—	—	—	—	—	—	94.44	2019	全国平均	94		GB/T 51366
4	烟煤	GJ	—	—	—	—	—	—	—	—	—	—	—	89.00	2019	全国平均	93		
5	褐煤	GJ	—	—	—	—	—	—	—	—	—	—	—	98.56	2019	全国平均	96		
6	炼焦煤	GJ	—	—	—	—	—	—	—	—	—	—	—	91.27	2019	全国平均	98		
7	型煤	GJ	—	—	—	—	—	—	—	—	—	—	—	110.88	2019	全国平均	90		
8	焦炭	GJ	—	—	—	—	—	—	—	—	—	—	—	100.60	2019	全国平均	93		
9	喷气煤油	GJ	—	—	—	—	—	—	—	—	—	—	—	70.07	2019	全国平均	98		
10	一般煤油	GJ	—	—	—	—	—	—	—	—	—	—	—	70.43	2019	全国平均	98		

Fig. 3-12 Tertiary interface for energy carbon emission factors,source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

能源–煤炭及煤制品碳排放因子

序号	名称	单位	原材料开采（kgCO₂e/单位）				燃烧（kgCO₂e/单位）				合计碳排放（kgCO₂e/单位）				年份代表性	区域代表性	碳氧化率（%）	不确定度（%）	来源
			CO₂	CH₄	NO₂	合计	CO₂	CH₄	NO₂	合计	CO₂	CH₄	NO₂	合计					
1	原煤	kg	0.09	0.26	0.00	0.35	1.98	0.01	0.01	2.00	2.07	0.27	0.01		2018	全国平均 ☑ 各省市平均 ☐ 区域平均 ☐ 企业平均 ☐ 典型厂家 ☐			GB/T 51366
2	标准煤	kg	—	—	—	—	2.77	0.01	0.01	2.79	2.77	0.01	0.01	2.79	2018		98		CBCED ☐ GB/T 51366 ☐ CPCFFD 2022 ☐ DH 2.0 ☐
3	无烟煤	GJ	—	—	—	—	—	—	—	—	—	—	—	94.44	2019		94		
4	烟煤	GJ	—	—	—	—	—	—	—	—	—	—	—	89.00		全国平均	93		
5	褐煤	GJ	—	—	—	—	—	—	—	—	—	—	—	98.56	2019	全国平均	96		
6	炼焦煤	GJ	—	—	—	—	—	—	—	—	—	—	—	91.27	2019	全国平均	98		
7	型煤	GJ	—	—	—	—	—	—	—	—	—	—	—	110.88	2019	全国平均	90		
8	焦炭	GJ	—	—	—	—	—	—	—	—	—	—	—	100.60	2019	全国平均	93		
9	喷气煤油	GJ	—	—	—	—	—	—	—	—	—	—	—	70.07	2019	全国平均	98		
10	一般煤油	GJ	—	—	—	—	—	—	—	—	—	—	—	70.43	2019	全国平均	98		

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Fig. 3-13 Energy Carbon Emission Factor Edit Screen,source: Architectural Design and Research Institute of Xi'an University of Architecture and Technology

4. INTERNATIONAL CARBON EMISSION FACTORS DATABASE FOR BUILDING MATERIALS

4.2 Construction Status of the International Building Materials Carbon Emission Factor Database

Since the 1970s, Western countries have taken the lead in conducting research on concentrations of greenhouse gases such as carbon dioxide and methane, as well as national greenhouse gas inventories, with a focus on carbon dioxide. To date, the institutions that have conducted in-depth research on carbon emissions of various countries worldwide include the International Energy Agency (IEA), the Joint Research Center of the European Union (JRCE), the U.S. Energy Information Administration (EIA), the Netherlands Environmental Assessment Agency (NEA), and the World Resources Institute (WRI) (Yu Yunxing, 2023). There are some problems that some authoritative carbon emission databases on China's local building carbon emission calculation research still exist. First of all, since 2005, various industries in China have been developing rapidly, and industries and technologies have been constantly adjusting and changing, and the parameters related to carbon emissions have also been changing. Therefore, it is worth studying how these carbon emission databases can select a suitable system of calculation methods to characterize China's localised carbon emission-related parameters (Qingqing Li, 2018).

Then, the accounting boundary of these databases is different, which can be easily ignored by researchers. For example, the accounting boundary of the International Energy Agency (IEA) and the U.S. Energy Information Administration (EIA) is the carbon emission from fossil fuel combustion, while the accounting boundary of the U.S. databases such as EDGAR includes the carbon emission from industrial production processes in addition to fossil fuel combustion. As a result, even for the same material in the same country, the results of the data from different organizations may be different, which makes it difficult to scientifically apply the data to characterize and evaluate building carbon emissions. This makes it difficult to scientifically apply the data to quantify and assess the carbon emissions of buildings over their life cycle. Therefore, it is necessary to improve the accuracy and precision of building carbon emission calculations to reflect the environmental impact of buildings.

Although there are more problems worth discussing, the international research experience on carbon emission factor database is still relatively more abundant, so this part will review and comment on the representative environmental impact databases in foreign countries, in order to provide reference and guidance for the standardized building carbon emission factor database to be constructed in this study.

In the world, the overall carbon emission research in Europe is relatively advanced, and there are many high-quality carbon emission factor databases. European laws and regulations are also very concerned about carbon emission calculation and reporting, for example, the EU ETS regulations emphasize the importance of improving the accounting method and propose the establishment of a coal quality database system to ensure the accuracy of carbon emission data. This shows Europe's concern to improve the quality of carbon emission data.

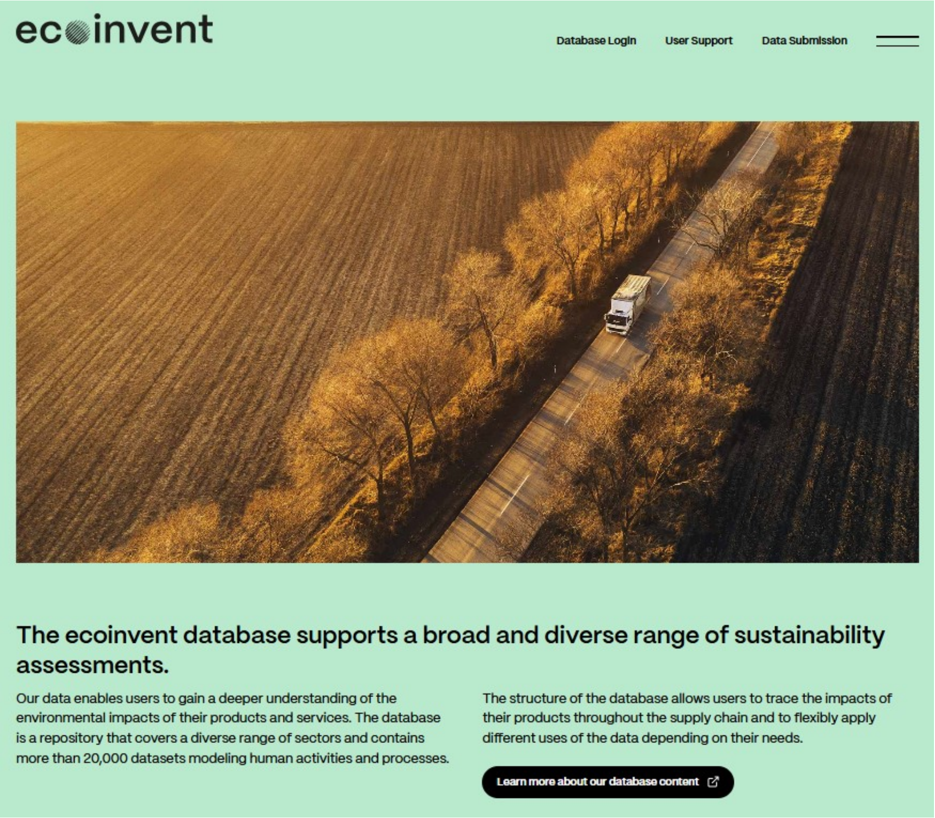
Some representative European databases are analyzed below, namely the Swiss Ecoinvent database and the Life Cycle Assessment database for the building sector"Ökobilanzdaten im Baubereich", as well as the German ÖKOBAUDAT database and the Dutch SimaPro, among others.

4.2 Database of European representative carbon emission factors

4.2.1 Swiss Ecoinvent Database

The Ecoinvent database is a commercial database developed by the Ecoinvent Center in Switzerland since 1990. The first, second, and third versions of the database were released in 2003, 2007, and 2013, respectively, and the latest version is Ecoinvent v3.10, whose home page is shown in Figure 4-1. The 3.10 update brings a wealth of enhancements to the building and construction sector of the Ecoinvent database, including a large amount of new data and several updates. Extensive information on clinker and different types of cement production and their corresponding market activities within the Tunisian geography has been added. The Swiss market database has been updated to remove outdated activities that do not correspond to the current production of building materials and now shows the latest data on clinker and cement production (including Portland cement, CEM II/A and CEM II/B) and their corresponding market activities. The database contains more than 19,000 individual process records and aggregated process records for the corresponding products.

Ecoinvent is widely recognized as one of the most comprehensive and transparent databases on the market and is used by more than 3,000 organizations worldwide.



The ecoinvent database supports a broad and diverse range of sustainability assessments.

Our data enables users to gain a deeper understanding of the environmental impacts of their products and services. The database is a repository that covers a diverse range of sectors and contains more than 20,000 datasets modeling human activities and processes.

The structure of the database allows users to trace the impacts of their products throughout the supply chain and to flexibly apply different uses of the data depending on their needs.

Fig. 4-1 Ecoinvent Home Page Diagram, source: Ecoinvent

The Ecoinvent database provides input-output inventories for thousands of goods and services processes covering agriculture and livestock, building and construction, chemicals and plastics, energy, forestry and wood, metals, textiles, transportation, tourism and accommodation, and waste treatment and recycling.

Specifically for the building and construction sector, the Ecoinvent database provides access to about 1,500 datasets on building minerals (e.g. sand, rock, lime, gypsum, natural stone), cement, concrete, alternative materials to concrete clinker (e.g. ground blast-furnace slag, calcined clay, etc.), glass, insulation materials (e.g. polystyrene, expanded vermiculite, asbestos, etc.), masonry, mortar, and so on. In addition, data on wood used in construction are available in the Forestry sector, and data on metals and metal tools used in construction are available in the Metals sector.

The data in Ecoinvent are mainly derived from statistics, industry sector data and literature. The inventory data sets on building materials and construction activities are mainly supported by the Fraunhofer Institute for Manufacturing Technology, the University of Campinas, the Federal University of Rio Grande do Sul, the University of Johannesburg, the Swiss Federal Laboratory for Materials Testing and Research (EMPA) and the Technical University of Graz.

The database has the following characteristics:

- The Ecoinvent database is a compliant data source based on ISO 14040 and ISO 14044;
- Ecoinvent is recognized as one of the more comprehensive LCI databases on the market, containing datasets for most industries and the database is updated annually;
- Ecoinvent v3.10 data is more transparent and traceable than previous versions, specifically it includes information on product attributes with access to the parameters and mathematical formulas behind the data, clarifying data uncertainty;
- Data can be provided at the unit process and system process level.

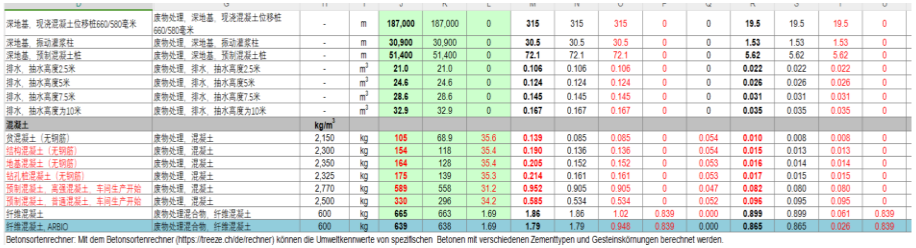
4.2.2 Ökobilanzdaten im Baubereich

The Swiss Life Cycle Assessment database (Ökobilanzdaten im Baubereich) for the building sector is updated mainly through online EXCEL files. Two files are available on the official website for users' reference. The first is the Life Cycle Assessment Data for the Building Sector 2009/1:2022 in PDF format, which is intended to provide planners with a starting point for understanding the subject. The document exhaustively covers typical Swiss data on building materials and construction technology (including production and disposal), energy, and transportation (covering operations, vehicles, and infrastructure).

The second file is the Life Cycle Assessment Data for the Construction Sector 2009/1:2022 in Excel format, which contains the results of the assessment for a number of key indicators. In addition, the Excel file provides manufacturer-specific data and detailed information on the different disposal methods for buildings.

The database uses the latest background dataset, the DETEC LCA dataset DQRv2 (version 2022), to calculate the LCA indicators. The new version of the Excel file provides detailed indicators on "primary energy consumption during material use", distinguishing between renewable and non-renewable energy sources, as well as the biogenic carbon content in kilograms of carbon. In addition, the database has been updated with new LCA indicators for specific building materials (including averages and products from specific manufacturers), building services equipment, energy systems, transportation systems, and waste management.

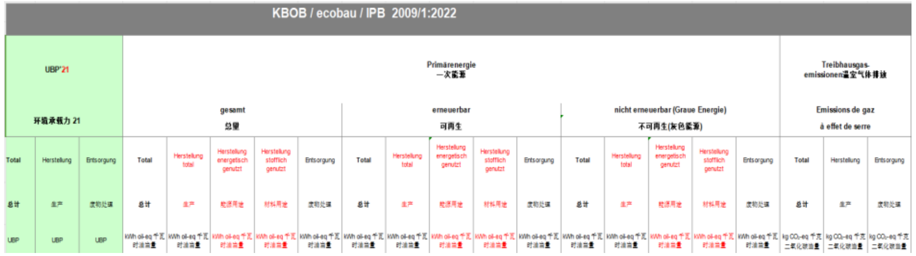
For example, in the case of concrete, as shown in Figure 4-2, detailed data are provided on several aspects of a material, including its environmental carrying capacity, its use as a primary energy source, and its greenhouse gas emissions and biogenic carbon, as shown in Figure 4-3. However, the current database interface is somewhat limited in its ability to display a single concrete category; for example, the author was unable to find parameters for different categories of concrete, such as C15 to C45.



深地基，现浇混凝土位移桩660/580毫米	废物处理，深地基，现浇混凝土位移桩660/580毫米	-	m	**187,000**	187,000	0	**315**	315	315	0	0	**19.5**	19.5	19.5	0
深地基，振动灌浆柱	废物处理，深地基，振动灌浆柱	-	m	**30,900**	30,900	0	**30.5**	30.5	30.5	0	0	**1.53**	1.53	1.53	0
深地基，预制混凝土桩	废物处理，深地基，预制混凝土桩	-	m	**51,400**	51,400	0	**72.1**	72.1	72.1	0	0	**5.62**	5.62	5.62	0
排水，抽水高度2.5米	废物处理，排水，抽水高度2.5米	-	m^3	**21.0**	21.0	0	**0.106**	0.106	0.106	0	0	**0.022**	0.022	0.022	0
排水，抽水高度5米	废物处理，排水，抽水高度5米	-	m^3	**24.6**	24.6	0	**0.124**	0.124	0.124	0	0	**0.026**	0.026	0.026	0
排水，抽水高度7.5米	废物处理，排水，抽水高度7.5米	-	m^3	**28.6**	28.6	0	**0.145**	0.145	0.145	0	0	**0.031**	0.031	0.031	0
排水，抽水高度为10米	废物处理，排水，抽水高度为10米	-	m^3	**32.9**	32.9	0	**0.167**	0.167	0.167	0	0	**0.035**	0.035	0.035	0
混凝土		**kg/m³**													
贫混凝土（无钢筋）	废物处理，混凝土	2,150	kg	**105**	68.9	35.6	**0.139**	0.085	0.085	0	0.054	**0.010**	0.008	0.008	0
结构混凝土（无钢筋）	废物处理，混凝土	2,300	kg	**154**	118	35.4	**0.190**	0.136	0.136	0	0.054	**0.015**	0.013	0.013	0
地基混凝土（无钢筋）	废物处理，混凝土	2,350	kg	**164**	128	35.4	**0.205**	0.152	0.152	0	0.053	**0.016**	0.014	0.014	0
钻孔桩混凝土（无钢筋）	废物处理，混凝土	2,325	kg	**175**	139	35.3	**0.214**	0.161	0.161	0	0.053	**0.017**	0.015	0.015	0
预制混凝土，高强混凝土，车间生产开始	废物处理，混凝土	2,770	kg	**589**	558	31.2	**0.952**	0.905	0.905	0	0.047	**0.082**	0.080	0.080	0
预制混凝土，普通混凝土，车间生产开始	废物处理，混凝土	2,500	kg	**330**	296	34.2	**0.585**	0.534	0.534	0	0.052	**0.096**	0.095	0.095	0
纤维混凝土	废物处理混合物，纤维混凝土	600	kg	**665**	663	1.69	**1.86**	1.86	1.02	0.839	0.000	**0.899**	0.899	0.061	0.839
纤维混凝土, ARBIO	废物处理混合物，纤维混凝土	600	kg	**639**	638	1.69	**1.79**	1.79	0.948	0.839	0.000	**0.865**	0.865	0.026	0.839

Betonsortenrechner: Mit dem Betonsortenrechner (https://treeze.ch/de/rechner) können die Umweltkennwerte von spezifischen Betonen mit verschiedenen Zementtypen und Gesteinskörnungen berechnet werden.

Fig. 4-2 Concrete Carbon Emission Factor Data, source: KBOB



KBOB / ecobau / IPB 2009/1:2022																				
UBP'21 环境承载力 21			Primärenergie 一次能源															Treibhausgas-emissionen温室气体排放		
			gesamt 总量					erneuerbar 可再生					nicht erneuerbar (Graue Energie) 不可再生(灰色能源)					Emissions de gaz à effet de serre		
Total	Herstellung	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung	Entsorgung
总计	生产	废物处理	总计	生产	能源用途	材料用途	废物处理	总计	生产	能源用途	材料用途	废物处理	总计	生产	能源用途	材料用途	废物处理	总计	生产	废物处理
UBP	UBP	UBP	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kWh oil-eq 千瓦时油当量	kg CO_2-eq 千克二氧化碳当量	kg CO_2-eq 千克二氧化碳当量	kg CO_2-eq 千克二氧化碳当量

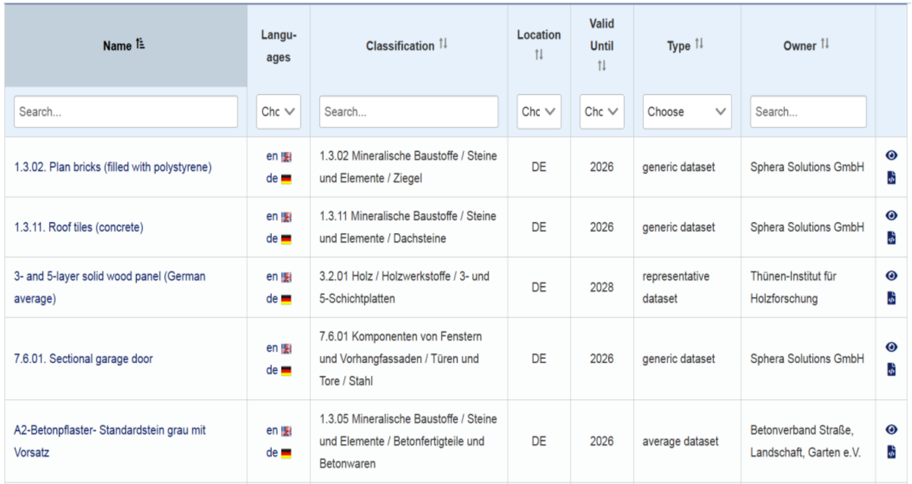
Fig. 4-3 Carbon Emission Factor Data Interface, source: KBOB

4.2.3 German ÖKOBAUDAT database

The ÖKOBAUDAT platform is offered as a standardized database for the ecological assessment of buildings. The core of the platform is an online database containing life cycle assessment data sets on building materials, construction, transportation, energy and disposal processes. The ÖKOBAUDAT database (current version 2024-I, released in October 2024) complies with EN 15804+A2 and is generated based on GaBi background data. The GaBi software is a software system first developed jointly by the German specialist company PEINTERNATIONAL and the Institute for Experimental and Scientific Research on Aggregates of the University of Stuttgart. The first version, GaBi 1.0, was developed in 1990 and included GaBi Build-it for LCA in the construction industry. This software is not limited to the sustainable development of the construction industry, but is a software that focuses on the sustainable development of all industries and their supply chains. The core of its product development and design is to introduce a range of sustainable products to build competitive advantage and increase user profitability, to help achieve strategic sustainability goals for each industry's products, and to identify supply chain management hotspots to reduce business risk by optimizing material use and improving processes.

All EPD datasets in this database comply with the "Principles for the acceptance of LCA data in ÖKOBAUDAT". Operators of licensed EPD programs can submit datasets to ÖKOBAUDAT on an ongoing basis, and a new ÖKOBAUDAT version is released about once a year when the common database is updated. In February 2020, the new standard DIN EN 15804+A2 was adopted with extensive changes to the impact indicators. As a result, impact indicators calculated according to the new version of the standard can no longer be compared with impact indicators according to the old DIN EN 15804+A1 and must not be used together. Consequently, the data sets according to DIN EN 15804+A2 are presented in a separate ÖKOBAUDAT database. They will be used in the future as a mandatory data source in the BNB.

According to the official website, there are more than 1,400 records in the database. The carbon emission factor query interface is shown in Figure 4-4, and the detailed carbon emission factor interface for specific building materials is shown in Figure 4-5. The website is very detailed about the sources of the carbon emission factor data, as well as the introduction of the main components of the data, which are process information, modeling and validation, administrative information, and environmental indicators, and the user is given advice on how to use the data in a considerate way. As for the specific information, the parameters are also listed in great detail, as shown in Figure 4-6.

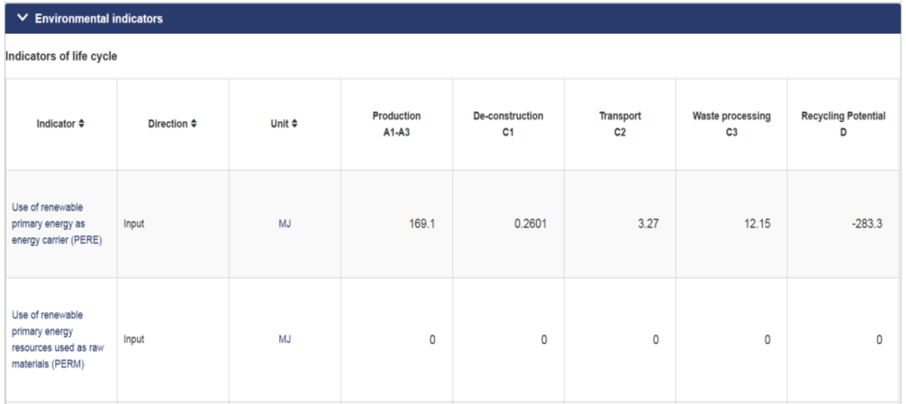


Name	Langu-ages	Classification	Location	Valid Until	Type	Owner	
Search...	Chc	Search...	Chc	Chc	Choose	Search...	
1.3.02. Plan bricks (filled with polystyrene)	en de	1.3.02 Mineralische Baustoffe / Steine und Elemente / Ziegel	DE	2026	generic dataset	Sphera Solutions GmbH	
1.3.11. Roof tiles (concrete)	en de	1.3.11 Mineralische Baustoffe / Steine und Elemente / Dachsteine	DE	2026	generic dataset	Sphera Solutions GmbH	
3- and 5-layer solid wood panel (German average)	en de	3.2.01 Holz / Holzwerkstoffe / 3- und 5-Schichtplatten	DE	2028	representative dataset	Thünen-Institut für Holzforschung	
7.6.01. Sectional garage door	en de	7.6.01 Komponenten von Fenstern und Vorhangfassaden / Türen und Tore / Stahl	DE	2026	generic dataset	Sphera Solutions GmbH	
A2-Betonpflaster- Standardstein grau mit Vorsatz	en de	1.3.05 Mineralische Baustoffe / Steine und Elemente / Betonfertigteile und Betonwaren	DE	2026	average dataset	Betonverband Straße, Landschaft, Garten e.V.	

Fig. 4-4 Carbon Emission Factor Data Search Interface, source: ÖKOBAUDAT

Process Data set: 1.3.02. Plan bricks (filled with polystyrene) (en) en de

Fig. 4-5 Carbon Emission Factor Data Detail Interface, source: ÖKOBAUDAT



Indicators of life cycle

Indicator	Direction	Unit	Production A1-A3	De-construction C1	Transport C2	Waste processing C3	Recycling Potential D
Use of renewable primary energy as energy carrier (PERE)	Input	MJ	169.1	0.2601	3.27	12.15	-283.3
Use of renewable primary energy resources used as raw materials (PERM)	Input	MJ	0	0	0	0	0

Fig. 4-6 Data Interface, source: ÖKOBAUDAT

4.2.4 Dutch SimaPro

In 1990, the PRé Sustainability team developed the first version of SimaPro to effectively address the problem of “measuring and evaluating ecological performance”.Today, large corporations, researchers and consultants are using the methods and tools developed by PRé to make more rational and effective decisions. PRé helps companies implement their sustainability strategies through fact-based consulting services, training, and software solutions based on whole-life cycle thinking.PRé has participated in and acted on many sustainability initiatives around the world, including the launch of the Industry-Led Roundtable for Product Social Metrics and the development of the widely recognized and applied environmental impact assessment methodology, ReCiPe & Eco—Indicator 99.SimaPro measures, improves, and communicates an organization's sustainability performance. It also helps companies develop effective strategies and integrate sustainability in supply chain management, product development, and organization in a coordinated manner.

SimaPro, PRé's flagship product, aims to create a vibrant ecosystem that connects different worlds, systems, people and companies to support strategies for a more sustainable future.

For computational analysis of data inventories or assessment of environmental impacts, SimaPro supports access to a wide range of databases, including the renowned Ecoinvent V3 database, the European and Danish Input/Output database and the US Life Cycle Inventory database (US LCI), as well as the , Agri-footprint, AGRIBALYSE, Carbon Minds, DATASMART LCI package, Environmental Footprint database, ESU world food LCA database, EXIOBASE, IDEA Japanese Inventory database, Industry data library: PlasticsEurope, ERASM, World Steel, Quanties World Food LCA Database, Social hotspots database, WEEE LCI database, and 15 other databases. Users can access the complete database by paying a fee.

4.3 Comprehensive comparison

A comprehensive comparison of Chinese and international databases shows that there are fewer specialized databases for building carbon emission factors and even fewer databases for building materials only, and most of the data on carbon emission factors for building materials account for a small category in the whole carbon emission factor database. In fact, most of the databases are the basic databases used in the LCA methodology to support the analysis of the whole life cycle inventory, which includes many industries, including construction, and covers many types of air pollutants, including GHGs.

As for the construction of the building carbon emission factor database itself, the German ÖKOBAUDAT data set is the most detailed among the above databases, but the corresponding information is too much, and the difficulty of obtaining the data directly is relatively increased. As for the scope of the data itself, it may change according to the regional environment, and the difficulty of verifying the specific value of the carbon emission factor varies from region to region. Switzerland's Ecoinvent is a world-renowned database of carbon emission factors, but it is not a single database dedicated to building materials, while Switzerland's Life Cycle Assessment Database (Ökobilanzdaten im Baubereich) is relatively more specialized, and the free and open data can provide references for many international researchers.

In comparison, many points can be learned from Europe in the process of building carbon emission database construction in China. For example, the frequency of updating needs to be regularly updated to reflect the latest changes in building materials and processes and cooperation and data sharing with international databases can be strengthened to improve the international applicability and recognition of data, which will be analyzed in the next chapter.

In conclusion, when building the database of carbon emission factors, it is necessary to make full use of international experience, refer to the advantages and disadvantages of each data set, take into account the complexity of data, regional applicability and other issues, and formulate a scientific and reasonable database construction plan to improve the efficiency and accuracy of data collection and ensure that it can effectively serve the accurate assessment and control of carbon emissions in the building industry.

5. ANALYSIS OF THE DEVELOPMENT DIRECTION OF CHINESE DATABASES

After analysis and comparison, it can be seen that there are many areas to be developed and improved for the establishment of a building carbon emission database in China, and some representatives will be specifically discussed below.

5.1 Improvement of the official unified building database and enrichment of local counterpart database information

First of all, it is imperative to establish an official unified building database as well as corresponding local databases. Although there is a national standard for building carbon emission calculation in China (GB/T 51366 - 2019), the use of building materials is diversified due to regional differences from a national perspective.

An official unified database can ensure the authority and standardization of the data, and provide a benchmark for building carbon emission calculations across the country. For example, the construction of Beijing Daxing International Airport, which involves a large number of new building materials and complex structures, would have a more accurate basis for calculating carbon emissions if supported by an official unified database.

At the same time, local databases can be tailored to local conditions, taking into account locally characteristic building materials and architectural styles. China's traditional dwellings are rich and diverse, and most of the building materials used are local specialties. For example, in the Fujian Tulou Restoration and Maintenance Project, local databases can be used to collect and organize data on local building materials, such as earth and wood, so that carbon emissions can be calculated more accurately.

5.2 Integration of calculation methods and increased data transparency

In order to ensure that the calculation of carbon emissions from building materials and the building process has uniform standards and methods, it is necessary to establish a standardized calculation system and develop corresponding reporting formats and communication rules. In addition, the current calculation method in GB51366 does not have clear guidance on uncertainty calculation, and in the actual process of carbon emission calculation, there are many uncertainties, such as errors in data measurement, assumptions in the calculation model, and market fluctuations.

The calculation method in the standard lacks the analysis and evaluation of these uncertainty factors, which affects the reliability and accuracy of the calculation results to some extent. For example, when measuring the energy consumption data of building materials, there may be errors in the data due to the accuracy of measuring instruments, differences in measuring methods, etc., but the standards do not specify the corresponding error range and uncertainty analysis methods.

Therefore, the carbon emission factor calculation method needs to be integrated and updated. In this way, we can ensure that the carbon emission data between different building projects are comparable, so as to provide a reliable basis for the management and reduction of carbon emissions.

In order to enhance the transparency and credibility of the data, it is essential to provide detailed reports on the system boundaries, calculation steps, and basic parameters that are involved in the calculation results. The system boundary should clearly define the scope of the accounting boundary, including which segments are included in the calculation and which segments are excluded.

The calculation steps should detail every aspect of the process, from data collection to the final result, to ensure the rigor and repeatability of the calculation process. These detailed reports can help prevent errors in calculation results due to incomplete information or misunderstandings and ensure that all stakeholders can accurately understand and use the carbon emissions data. This not only supports the management of building carbon emissions in the construction industry but also promotes the awareness and promotion of low-carbon buildings in society as a whole.

5.3 Enhancement of the functional completeness of the building database

A well-functioning database is the key to improving its usability. The database should meet the four basic functional requirements of import, edit, query and export. The import function makes it easy to incorporate newly acquired carbon emission data of building materials into the database, either from new research results or feedback from building materials enterprises. The editing function allows professionals to correct and update the data to adapt to changing circumstances.

For example, when it is found that the improvement of a certain building material production process leads to a change in carbon emissions, it can be edited in a timely manner. The query function is particularly important, and the interface should be guided so that data can be found quickly. By designing a clear categorization and search guide, for example, by building material type, production process, etc., users can quickly locate the carbon emission data they need. The export function makes it easy to use the data in different application scenarios, such as architectural design software and green building consulting reports.

When designing buildings, architects need to frequently query and use the carbon emission data of building materials. Suppose the database has good import, editing, querying, and exporting functions. In that case, accurate data can be easily obtained for carbon emission calculation in the design phase, allowing better optimization of the design scheme and reduction of building carbon emissions throughout the life cycle. Moreover, it will be more convenient to transfer data between different projects, improving work efficiency.

In conclusion, by establishing a comprehensive database system combining official and local data and ensuring that the database has comprehensive and practical functions, the carbon emission data of China's building materials will develop in a more scientific and accurate direction, providing strong support for the energy-saving and emission reduction goals of the construction industry, and pushing China's building sector to take a solid step forward on the road to carbon neutrality. This is not only conducive to combating climate change but will also promote the sustainable development of the construction industry and enhance the green competitiveness of the whole industry.

A1. References

- Zhao,Y. , Liu,L. ,&Yu , M.(2023.)Comparison and analysis of carbon emissions of traditional, prefabricated, and green material buildings in materialization phase.[J].Journal of Cleaner Production.406,137-152.
- Hossain, M. U., & Poon, C. S. (2018). Global warming potential and energy consumption of temporary works in building construction. Journal of Cleaner Production, 172, 227-237.
- Abergel, J. Dulac, I. Hamilton, M. Jordan, and A. J. E. P. Pradeep,2019Abergel, T., Dean, B., & Dulac, J. (2019). Global status report for buildings and construction 2019. International Energy Agency
- Wasim, M., Ngo, T. D., & Law, D. (2022). Strategies for sustainable concrete: A review. Cement and Concrete Composites, 104, 103375.
- Li L ,Chen K.(2017).Quantitative assessment of carbon dioxide emissions in construction projects: A case study in Shenzhen[J].Journal of Cleaner Production,141394-408.
- Guohao Wang,Tengqi Luo,Haizhi Luo,Ran Liu,Yanhua Liu & Zhengguang Liu.(2024).A comprehensive review of building lifecycle carbon emissions and reduction approaches.[J].City and Built Environment,(1),12-12.
- Gustavsson, L., Joelsson, A., & Sathre, R. (2006). Life cycle primary energy use and carbon emission of wood-frame apartment. Building and Environment, 41(7), 940-951.
- Cho S H, Chae C U.(2016). A study on life cycle CO_2 emissions of low-carbon building in South Korea[J]. Sustainability, 8(6): 579.
- Sandanayake, M., Zhang, G., & Setunge, S. (2016). Environmental emissions at foundation construction stage of buildings – Two case studies. Building and Environment, 95, 189-198.
- Zhang X C, Wang F L. (2022).Carbon Emission Measurement in Construction Engineering[M]. Beijing: China Machine Press.
- Wu, G. (2021). Carbon emission calculation for buildings. China Architecture & Building Press.
- Sponsored and prepared by China Academy of Building Research, ltd. and Beijing Constitutive Power Engineering, ltd.; edited by Xia Xuyong, Li Shuyang, Zhang Yongwei, Cui Jing, Zhu Fenglei, and Wang Menglin. (2023). Building Carbon Emission Design Guide [M]. Beijing: China Construction Industry Press.
- Ministry of Housing and Urban-Rural Development of the People's Republic of China, ed. (2019).Standard for Calculating Carbon Emissions from Buildings [M].Beijing: China Construction Industry Press.
- Chen X L, Li X G, Lv Z H et al.(2023)A study on the evaluation of energy and carbon reduction benefits of green building materials labeling chapter in the Republic of China[J].Taiwan.
- China Building Energy Consumption and Carbon Emission Research Report (2023)[J].Architecture,2024,(02):46-59.
- Luo Z X.(2016). Research on Calculation Methods and Emission Reduction Strategies of CO_2 Emissions in Building Life Cycle [D].Xi'an University of Architecture and Technology.
- Yu Y X.(2023). Research on Standardized Measurement Method and Database of Carbon Emission Factors for Building Design [D].Xi'an University of Architecture and Technology.
- Li Q Q, Su Y, Li S, Wei Wei & Maohua Wang. (2018). Comparative Analysis of

International Typical Carbon Databases for Carbon Emission Accounting in China. Advances in Climate Change Research (03), 275-280.

- International Energy Agency (IEA). CO_2 emissions from fuelcombustion highlights 2016 [R]. Paris, France, 2016: 1-166.

- U.S. Energy Information Administration (EIA) U.S. Energy Information Administration [EB/OL]. 2017 [2017-06-09].

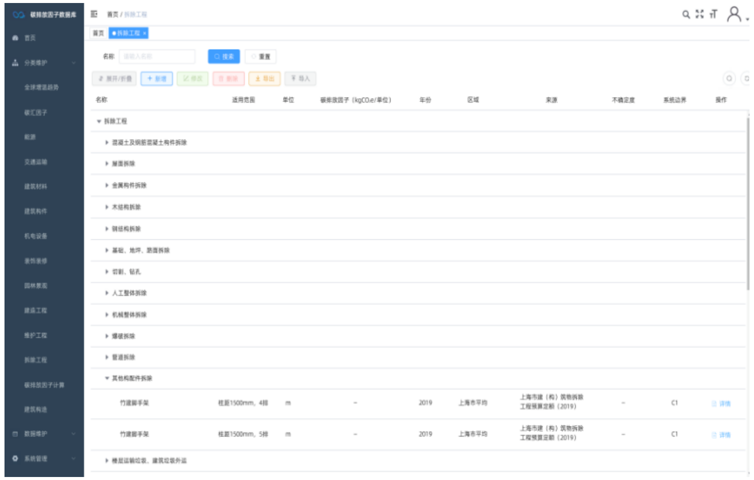
- Boden T A, Andres R J, Marland G. Carbon dioxide informationcenter [EB/OL]. 2017 [2017-07-041.

- Olivier J, Janssens-Maenhout G, Muntean M, et al. Joint researchcenter. Emissions database for global atmospheric research [EB/OL]. 2017 [2017-07-04].

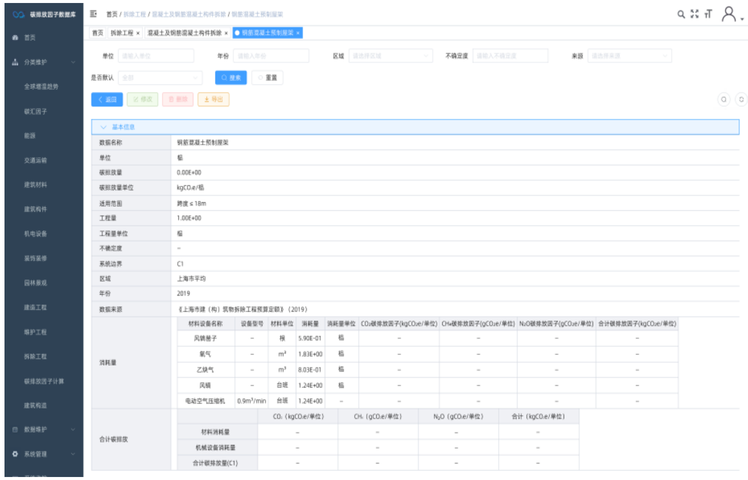
A2. Detailed interface for each type of data in the Ouroboros Carbon Emission Factor Database

Type | **Detailed interface**

Dismantling



名称	适用范围	单位	碳排放因子（kgCO_2e/单位）	年份	区域	来源	不确定度	系统边界	操作
▾ 拆除工程									
▸ 混凝土及钢筋混凝土构件拆除									
▸ 屋面拆除									
▸ 金属构件拆除									
▸ 木结构拆除									
▸ 钢结构拆除									
▸ 基础、地坪、路面拆除									
▸ 切割、钻孔									
▸ 人工整体拆除									
▸ 机械整体拆除									
▸ 爆破拆除									
▸ 管道拆除									
▾ 其他构配件拆除									
竹建脚手架	柱距1500mm，4排	m	–	2019	上海市平均	上海市建（构）筑物拆除工程预算定额（2019）	–	C1	详情
竹建脚手架	柱距1500mm，5排	m	–	2019	上海市平均	上海市建（构）筑物拆除工程预算定额（2019）	–	C1	详情
▸ 楼层运输垃圾、建筑垃圾外运									



基本信息

数据名称	钢筋混凝土预制屋架
单位	榀
碳排放量	0.00E+00
碳排放量单位	kgCO_2e/榀
适用范围	跨度 ≤ 18m
工程量	1.00E+00
工程量单位	榀
不确定度	–
系统边界	C1
区域	上海市平均
年份	2019
数据来源	《上海市建（构）筑物拆除工程预算定额》（2019）

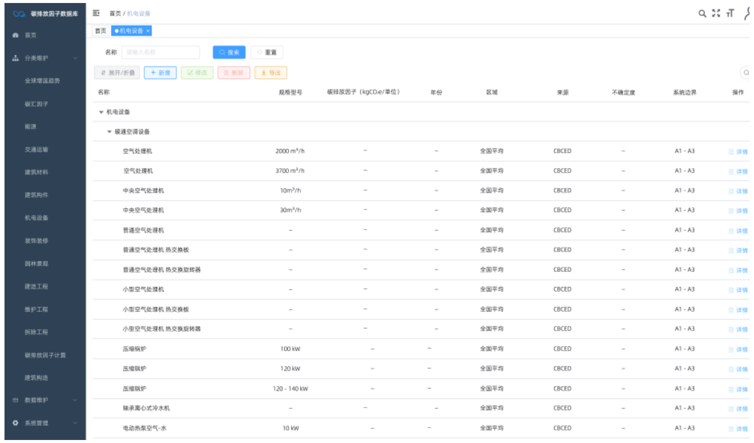
消耗量

材料设备名称	设备型号	材料单位	消耗量	消耗量单位	CO_2碳排放因子(kgCO_2e/单位)	CH_4碳排放因子(gCO_2e/单位)	N_2O碳排放因子(gCO_2e/单位)	合计碳排放因子(kgCO_2e/单位)
风镐凿子	–	根	5.90E-01	榀	–	–	–	–
氧气	–	m³	1.83E+00	榀	–	–	–	–
乙炔气	–	m³	8.03E-01	榀	–	–	–	–
风镐	–	台班	1.24E+00	榀	–	–	–	–
电动空气压缩机	0.9m³/min	台班	1.24E+00	–	–	–	–	–

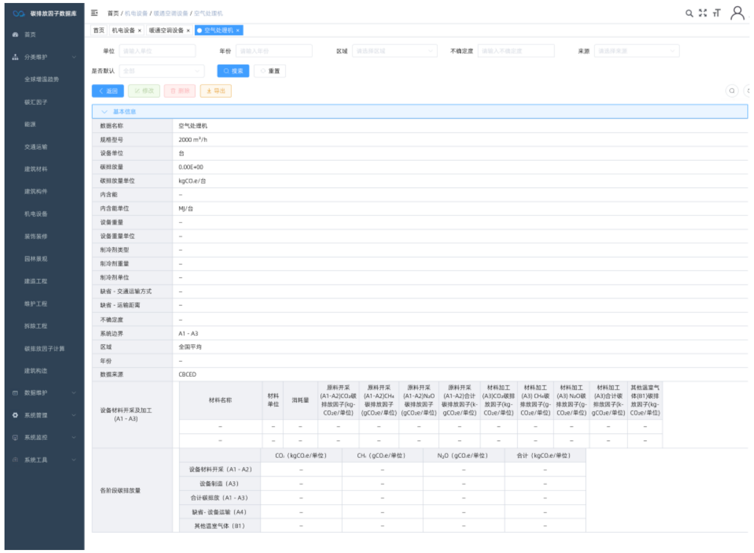
合计碳排放

	CO_2（kgCO_2e/单位）	CH_4（gCO_2e/单位）	N_2O（gCO_2e/单位）	合计（kgCO_2e/单位）
材料消耗量	–	–	–	–
机械设备消耗量	–	–	–	–
合计碳排放量(C1)	–	–	–	–

Electromechanical equipment



名称	规格型号	碳排放因子（kgCO_2e/单位）	年份	区域	来源	不确定度	系统边界	操作
▾ 机电设备								
▾ 暖通空调设备								
空气处理机	2000 m³/h	–	–	全国平均	CBCED	–	A1 - A3	详情
空气处理机	3700 m³/h	–	–	全国平均	CBCED	–	A1 - A3	详情
中央空气处理机	10m³/h	–	–	全国平均	CBCED	–	A1 - A3	详情
中央空气处理机	30m³/h	–	–	全国平均	CBCED	–	A1 - A3	详情
普通空气处理机	–	–	–	全国平均	CBCED	–	A1 - A3	详情
普通空气处理机 热交换板	–	–	–	全国平均	CBCED	–	A1 - A3	详情
普通空气处理机 热交换旋转器	–	–	–	全国平均	CBCED	–	A1 - A3	详情
小型空气处理机	–	–	–	全国平均	CBCED	–	A1 - A3	详情
小型空气处理机 热交换板	–	–	–	全国平均	CBCED	–	A1 - A3	详情
小型空气处理机 热交换旋转器	–	–	–	全国平均	CBCED	–	A1 - A3	详情
压缩锅炉	100 kW	–	–	全国平均	CBCED	–	A1 - A3	详情
压缩锅炉	120 kW	–	–	全国平均	CBCED	–	A1 - A3	详情
压缩锅炉	120 - 140 kW	–	–	全国平均	CBCED	–	A1 - A3	详情
轴承离心式冷水机	–	–	–	全国平均	CBCED	–	A1 - A3	详情
电动热泵空气-水	10 kW	–	–	全国平均	CBCED	–	A1 - A3	详情



基本信息

数据名称	空气处理机
规格型号	2000 m³/h
设备单位	台
碳排放量	0.00E+00
碳排放量单位	kgCO_2e/台
内含能	–
内含能单位	MJ/台
设备重量	–
设备重量单位	–
制冷剂类型	–
制冷剂重量	–
制冷剂单位	–
缺省 - 交通运输方式	–
缺省 - 运输距离	–
不确定度	–
系统边界	A1 - A3
区域	全国平均
年份	–
数据来源	CBCED

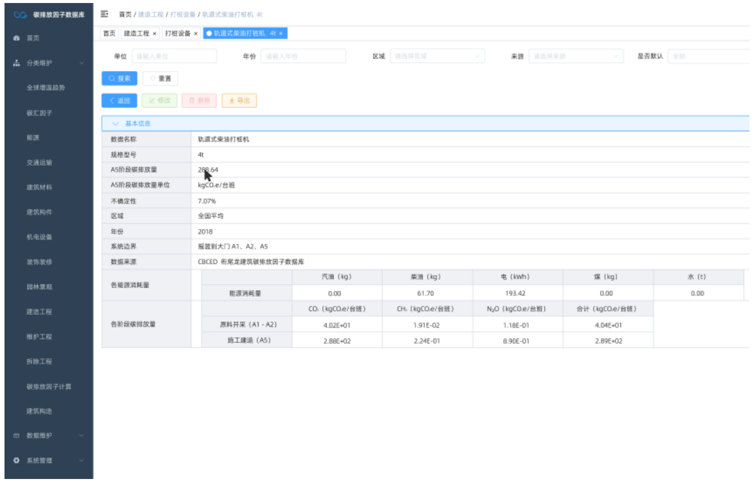
设备材料开采及加工（A1 - A3）

材料名称	材料单位	消耗量	原料开采(A1-A2)CO_2碳排放因子(kg-CO_2e/单位)	原料开采(A1-A2)CH_4碳排放因子(gCO_2e/单位)	原料开采(A1-A2)N_2O碳排放因子(gCO_2e/单位)	原料开采(A1-A2)合计碳排放因子(k-gCO_2e/单位)	材料加工(A3)CO_2碳排放因子(kg-CO_2e/单位)	材料加工(A3) CH_4碳排放因子(g-CO_2e/单位)	材料加工(A3) N_2O碳排放因子(g-CO_2e/单位)	材料加工(A3)合计碳排放因子(k-gCO_2e/单位)	其他温室气体(B1)碳排放因子(kg-CO_2e/单位)
–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–

各阶段碳排放量

	CO_2（kgCO_2e/单位）	CH_4（gCO_2e/单位）	N_2O（gCO_2e/单位）	合计（kgCO_2e/单位）
设备材料开采（A1 - A2）	–	–	–	–
设备制造（A3）	–	–	–	–
合计碳排放（A1 - A3）	–	–	–	–
缺省- 设备运输（A4）	–	–	–	–
其他温室气体（B1）	–	–	–	–

construction work



数据名称	轨道式柴油打桩机
规格型号	4t
A5阶段碳排放量	288.64
A5阶段碳排放量单位	kgCO$_2$e/台班
不确定性	7.07%
区域	全国平均
年份	2018
系统边界	摇篮到大门 A1、A2、A5
数据来源	CBCED 衙尾龙建筑碳排放因子数据库

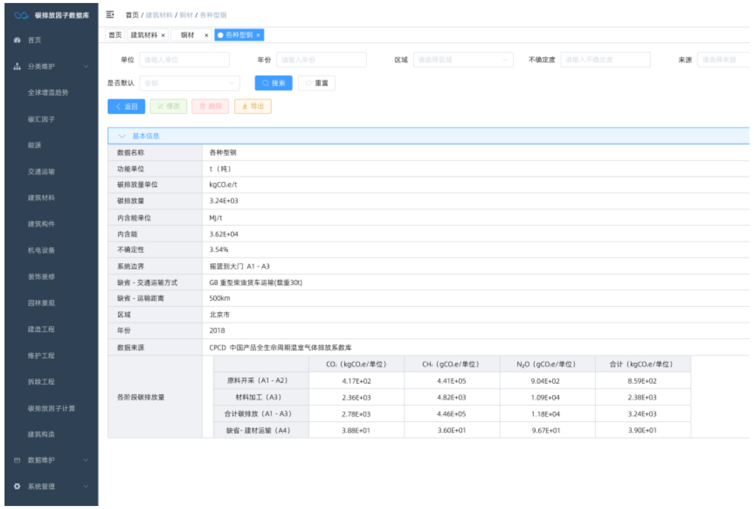
各能源消耗量

	汽油（kg）	柴油（kg）	电（kWh）	煤（kg）	水（t）
能源消耗量	0.00	61.70	193.42	0.00	0.00

各阶段碳排放量

	CO$_2$（kgCO$_2$e/台班）	CH$_4$（kgCO$_2$e/台班）	N$_2$O（kgCO$_2$e/台班）	合计（kgCO$_2$e/台班）
原料开采（A1 - A2）	4.02E+01	1.91E-02	1.18E-01	4.04E+01
施工建造（A5）	2.88E+02	2.24E-01	8.90E-01	2.89E+02

building material

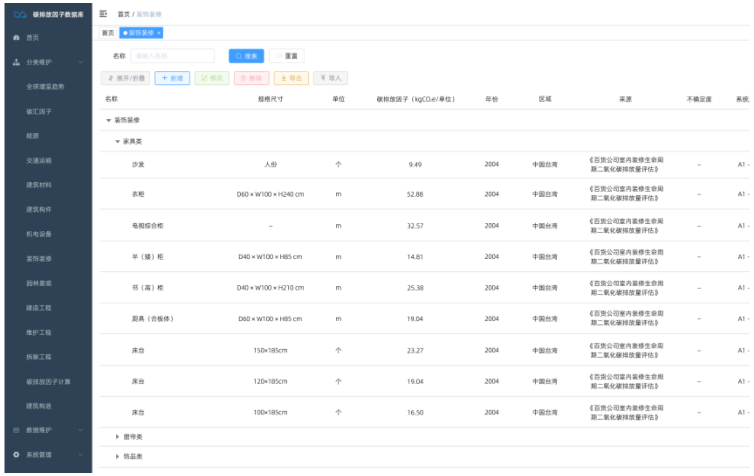


数据名称	各种型钢
功能单位	t（吨）
碳排放量单位	kgCO$_2$e/t
碳排放量	3.24E+03
内含能单位	MJ/t
内含能	3.62E+04
不确定性	3.54%
系统边界	摇篮到大门 A1 - A3
缺省 - 交通运输方式	GB 重型柴油货车运输(载重30t)
缺省 - 运输距离	500km
区域	北京市
年份	2018
数据来源	CPCD 中国产品全生命周期温室气体排放系数库

各阶段碳排放量

	CO$_2$（kgCO$_2$e/单位）	CH$_4$（gCO$_2$e/单位）	N$_2$O（gCO$_2$e/单位）	合计（kgCO$_2$e/单位）
原料开采（A1 - A2）	4.17E+02	4.41E+05	9.04E+02	8.59E+02
材料加工（A3）	2.36E+03	4.82E+03	1.09E+04	2.38E+03
合计碳排放（A1 - A3）	2.78E+03	4.46E+05	1.18E+04	3.24E+03
缺省- 建材运输（A4）	3.88E+01	3.60E+01	9.67E+01	3.90E+01

Decoration



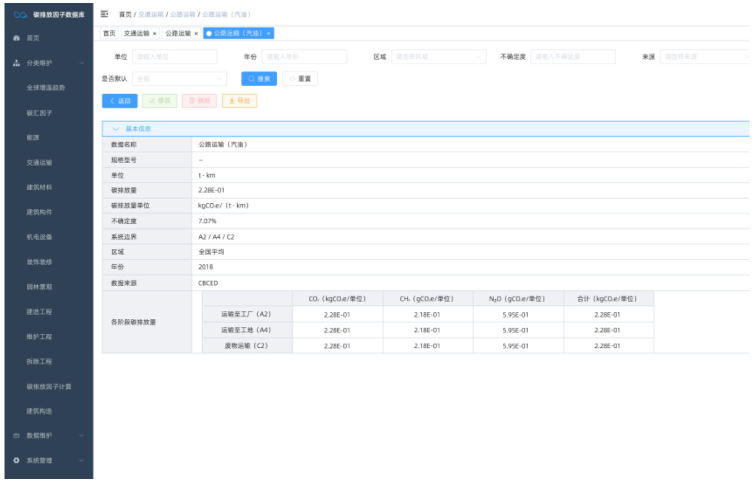
名称	规格尺寸	单位	碳排放因子（kgCO$_2$e/单位）	年份	区域	来源	不确定度	系统
▾ 装饰装修								
▾ 家具类								
沙发	人份	个	9.49	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
衣柜	D60 × W100 × H240 cm	m	52.88	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
电视综合柜	–	m	32.57	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
半（矮）柜	D40 × W100 × H85 cm	m	14.81	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
书（高）柜	D40 × W100 × H210 cm	m	25.38	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
厨具（合板体）	D60 × W100 × H85 cm	m	19.04	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
床台	150×185cm	个	23.27	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
床台	120×185cm	个	19.04	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
床台	100×185cm	个	16.50	2004	中国台湾	《百货公司室内装修生命周期二氧化碳排放量评估》	–	A1 -
▸ 窗帘类								
▸ 饰品类								

Building components

名称	单位	碳排放因子（kgCO$_2$e/单位）	年份	区域	来源	不确定度
▾ 建筑构件						
▾ 台阶						
混凝土台阶	m^2	173.00	2022	陕西省平均	CBCED	–
水泥砂浆面层台阶	m^2	186.00	2022	陕西省平均	CBCED	–
地砖面层台阶	m^2	187.00	2022	陕西省平均	CBCED	–
剁斧石面层台阶	m^2	191.00	2022	陕西省平均	CBCED	–
花岗石板面层台阶	m^2	192.00	2022	陕西省平均	CBCED	–
条石台阶	m^2	220.00	2022	陕西省平均	CBCED	–
▸ 坡道						
▸ 散水						
▸ 防潮层						
▸ 外墙饰面						
▸ 地面						
▸ 楼面						
▸ 踢脚						
▸ 内墙饰面						
▸ 屋面						

transportation

名称	单位	碳排放因子（kgCO_2e/单位）	年份	区域	来源	不确定度	系统边
▾ 交通运输							
▾ 公路运输							
轻型货车运输	t · km	0.083	2021	全国平均	CPCD	5.59%	A2 / A4
重型天然气自卸车货运服务	t · km	0.064	2022	全国平均	CPCD	5.59%	A2 / A4
重型柴油自卸车货运服务	t · km	0.101	2022	全国平均	CPCD	5.59%	A2 / A4
重型氢燃料自卸车货运服务	t · km	0.23	2022	全国平均	CPCD	5.59%	A2 / A4
重型纯电自卸车货运服务	t · km	0.077	2022	全国平均	CPCD	5.59%	A2 / A4
重型货车货运服务	km	0.598	2014	中国广东	CPCD	5.59%	A2 / A4
重型货车运输	t · km	0.049	2021	全国平均	CPCD	5.59%	A2 / A4
汽车（1650kg）	km	0.11	2022	全国平均	CPCD	5.59%	A2 / A4
汽车（1850kg）	km	0.20	2022	全国平均	CPCD	5.59%	A2 / A4
汽车（1490kg）	km	0.21	2022	全国平均	CPCD	5.59%	A2 / A4
汽车（1530kg）	km	0.20	2022	全国平均	CPCD	5.59%	A2 / A4
汽车	km	0.15	2022	全国平均	CPCD	5.59%	A2 / A4
燃料电池汽车	km	0.20	2017	北京市	CPCD	5.59%	A2 / A4
轻型汽油货车运输（载重2t）- 《江苏省民用建筑碳排放计算导则（征求意见稿）》	t · km	0.33	2023	中国江苏	–	7.07%	A2 / A4



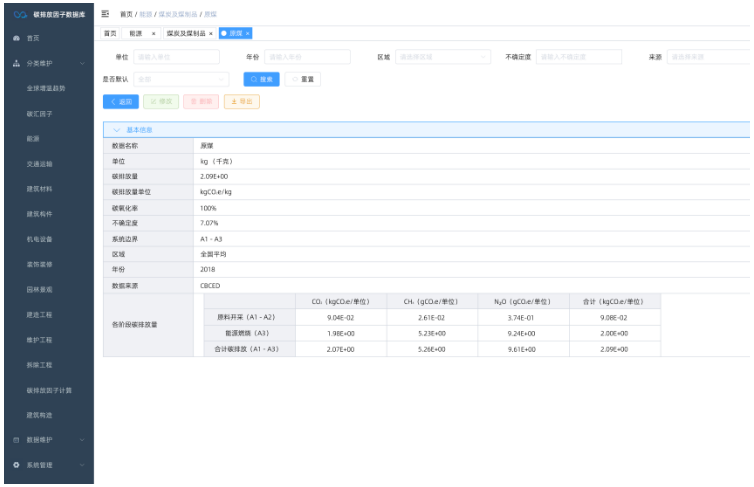
数据名称	公路运输（汽油）
规格型号	–
单位	t · km
碳排放量	2.28E-01
碳排放量单位	kgCO_2e/（t · km）
不确定度	7.07%
系统边界	A2 / A4 / C2
区域	全国平均
年份	2018
数据来源	CBCED

各阶段碳排放量

	CO_2（kgCO_2e/单位）	CH_4（gCO_2e/单位）	N_2O（gCO_2e/单位）	合计（kgCO_2e/单位）
运输至工厂（A2）	2.28E-01	2.18E-01	5.95E-01	2.28E-01
运输至工地（A4）	2.28E-01	2.18E-01	5.95E-01	2.28E-01
废物运输（C2）	2.28E-01	2.18E-01	5.95E-01	2.28E-01

energy

名称	单位	碳排放因子（kgCO_2e/单位）	年份	区域	来源	不确定度
▾ 能源						
▾ 煤炭及煤制品						
炼厂煤气	m³	3040.00	2011	亚洲	CPCD	5.59%
炼焦油	t	2645.00	2011	亚洲	CPCD	5.59%
烟煤（kg）	kg	2.10	2014	北京市	CPCD	5.59%
烟煤（t）	t	1870.00	2011	全国平均	CPCD	5.59%
焦炉气	t	1183.00	2008	亚洲	CPCD	5.59%
焦炭	t	3390.00	2011	全国平均	CPCD	5.59%
煤制天然气（kg）	kg	13.46	2015	全国平均	CPCD	3.54%
煤制天然气（t）	t	99.40	2018	全国平均	CPCD	3.54%
煤矸石	t	1590.00	2013	亚洲	CPCD	3.54%
褐煤	kWh	0.98	2011	全国平均	CPCD	3.54%
转炉煤气	m³	1.51	2012	全国平均	CPCD	3.54%
重油催化裂解煤气	kg	0.44	2021	全国平均	CPCD	5.59%
重油热解煤气	kg	0.81	2021	全国平均	CPCD	5.59%
无烟煤TJ - 《江苏省民用建筑碳排放计算导则（征求意见稿）》	TJ	94.44	2023	中国江苏	–	7.07%



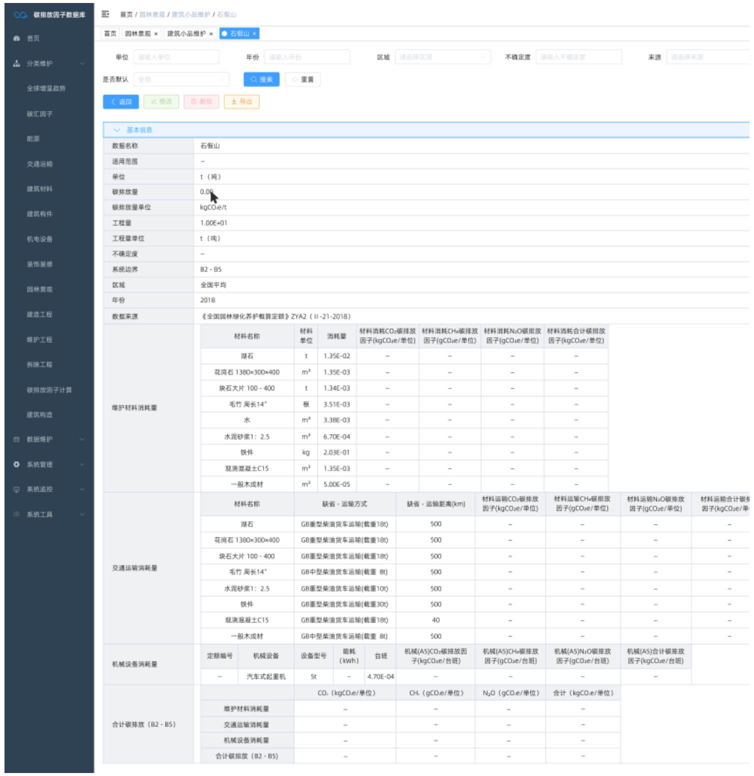
数据名称	原煤
单位	kg（千克）
碳排放量	2.09E+00
碳排放量单位	kgCO_2e/kg
碳氧化率	100%
不确定度	7.07%
系统边界	A1 - A3
区域	全国平均
年份	2018
数据来源	CBCED

各阶段碳排放量

	CO_2（kgCO_2e/单位）	CH_4（gCO_2e/单位）	N_2O（gCO_2e/单位）	合计（kgCO_2e/单位）
原料开采（A1 - A2）	9.04E-02	2.61E-02	3.74E-01	9.08E-02
能源燃烧（A3）	1.98E+00	5.23E+00	9.24E+00	2.00E+00
合计碳排放（A1 - A3）	2.07E+00	5.26E+00	9.61E+00	2.09E+00

gardening

名称	适用范围	单位	碳排放因子（kgCO$_2$e/单位）	年份	区域	来源	系
▾ 园林景观							
▾ 一级绿地养护							
常绿乔木	胸径10cm以内	株 · a	0.68	2018	全国平均	《全国园林绿化养护概算定额》ZYA2（II-21-2018）	
常绿乔木	胸径20cm以内	株 · a	0.82	2018	全国平均	《全国园林绿化养护概算定额》ZYA2（II-21-2018）	
常绿乔木	胸径30cm以内	株 · a	0.97	2018	全国平均	《全国园林绿化养护概算定额》ZYA2（II-21-2018）	
常绿乔木	胸径40cm以内	株 · a	1.12	2018	全国平均	《全国园林绿化养护概算定额》ZYA2（II-21-2018）	
▸ 二级绿地养护							
▸ 三级绿地养护							
▸ 其他绿化养护							
▾ 建筑小品维护							
花架、廊	钢结构	m^2	–	2018	全国平均	《全国园林绿化养护概算定额》ZYA2（II-21-2018）	
花架、廊	混凝土	m^2	–	2018	全国平均	《全国园林绿化养护概算定额》ZYA2（II-21-2018）	
石假山	–	t	–	2018	全国平均	《全国园林绿化养护概算定额》ZYA2（II-21-2018）	



数据名称	石假山
适用范围	–
单位	t（吨）
碳排放量	0.00
碳排放量单位	kgCO$_2$e/t
工程量	1.00E+01
工程量单位	t（吨）
不确定度	–
系统边界	B2 - B5
区域	全国平均
年份	2018
数据来源	《全国园林绿化养护概算定额》ZYA2（II-21-2018）

维护材料消耗量

材料名称	材料单位	消耗量	材料消耗CO$_2$碳排放因子(kgCO$_2$e/单位)	材料消耗CH$_4$碳排放因子(gCO$_2$e/单位)	材料消耗N$_2$O碳排放因子(gCO$_2$e/单位)	材料消耗合计碳排放因子(kgCO$_2$e/单位)
湖石	t	1.35E-02	–	–	–	–
花岗石 1380×300×400	m^3	1.35E-03	–	–	–	–
块石大片 100 - 400	t	1.34E-03	–	–	–	–
毛竹 周长14"	根	3.51E-03	–	–	–	–
水	m^3	3.38E-03	–	–	–	–
水泥砂浆1：2.5	m^3	6.70E-04	–	–	–	–
铁件	kg	2.03E-01	–	–	–	–
现浇混凝土C15	m^3	1.35E-03	–	–	–	–
一般木成材	m^3	5.00E-05	–	–	–	–

交通运输消耗量

材料名称	缺省 - 运输方式	缺省 - 运输距离(km)	材料运输CO$_2$碳排放因子(kgCO$_2$e/单位)	材料运输CH$_4$碳排放因子(gCO$_2$e/单位)	材料运输N$_2$O碳排放因子(gCO$_2$e/单位)	材料运输合计碳排放因子(kgCO$_2$e/单
湖石	GB重型柴油货车运输(载重18t)	500	–	–	–	–
花岗石 1380×300×400	GB重型柴油货车运输(载重18t)	500	–	–	–	–
块石大片 100 - 400	GB重型柴油货车运输(载重18t)	500	–	–	–	–
毛竹 周长14"	GB中型柴油货车运输(载重 8t)	500	–	–	–	–
水泥砂浆1：2.5	GB重型柴油货车运输(载重10t)	500	–	–	–	–
铁件	GB重型柴油货车运输(载重30t)	500	–	–	–	–
现浇混凝土C15	GB重型柴油货车运输(载重18t)	40	–	–	–	–
一般木成材	GB中型柴油货车运输(载重 8t)	500	–	–	–	–

机械设备消耗量

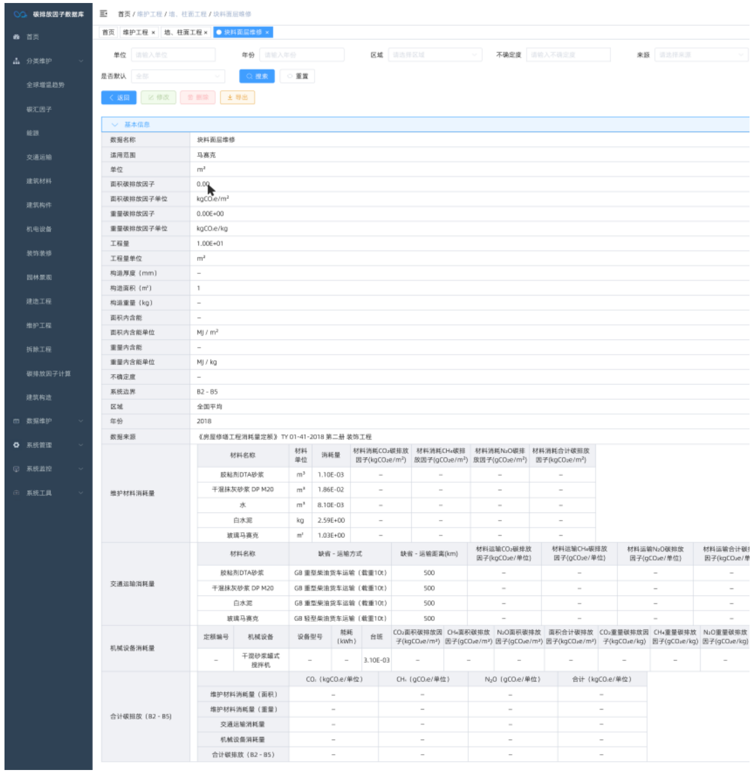
定额编号	机械设备	设备型号	能耗（kWh）	台班	机械(A5)CO$_2$碳排放因子(kgCO$_2$e/台班)	机械(A5)CH$_4$碳排放因子(gCO$_2$e/台班)	机械(A5)N$_2$O碳排放因子(gCO$_2$e/台班)	机械(A5)合计碳排放因子(kgCO$_2$e/台班)
–	汽车式起重机	5t	–	4.70E-04	–	–	–	–

合计碳排放（B2 - B5）

	CO$_2$（kgCO$_2$e/单位）	CH$_4$（gCO$_2$e/单位）	N$_2$O（gCO$_2$e/单位）	合计（kgCO$_2$e/单位）
维护材料消耗量	–	–	–	–
交通运输消耗量	–	–	–	–
机械设备消耗量	–	–	–	–
合计碳排放（B2 - B5）	–	–	–	–

Building maintenance

名称	适用范围	单位	碳排放因子（kgCO$_2$e/单位）	年份	区域	来源	不确定度	系统
▾ 维护工程								
▸ 拆除工程								
▸ 门窗工程								
▸ 楼地面工程								
▸ 墙、柱面工程								
块料面层整修	马赛克	m^2	–	2018	全国平均	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程	–	B2
块料面层整修	瓷板	m^2	–	2018	全国平均	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程	–	B2
块料面层整修	陶瓷面砖	m^2	–	2018	全国平均	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程	–	B2
块料面层整修	石材	m^2	–	2018	全国平均	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程	–	B2
零星修补	钢板网	m^2	–	2018	全国平均	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程	–	B2
零星修补	板条	m^2	–	2018	全国平均	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程	–	B2
墙面抹灰（内墙）	（14+6）mm	m^2	–	2018	全国平均	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程	–	B2
墙面抹灰（外墙）	（14+6）mm	m^2	–	2018	全国平均	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程	–	B2



数据名称	块料面层维修
适用范围	马赛克
单位	m^2
面积碳排放因子	0.00
面积碳排放因子单位	kgCO$_2$e/m^2
重量碳排放因子	0.00E+00
重量碳排放因子单位	kgCO$_2$e/kg
工程量	1.00E+01
工程量单位	m^2
构造厚度（mm）	–
构造面积（m^2）	1
构造重量（kg）	–
面积内含能	–
面积内含能单位	MJ / m^2
重量内含能	–
重量内含能单位	MJ / kg
不确定度	–
系统边界	B2 - B5
区域	全国平均
年份	2018
数据来源	《房屋修缮工程消耗量定额》TY 01-41-2018 第二册 装饰工程

维护材料消耗量

材料名称	材料单位	消耗量	材料消耗CO$_2$碳排放因子(kgCO$_2$e/m^2)	材料消耗CH$_4$碳排放因子(gCO$_2$e/m^2)	材料消耗N$_2$O碳排放因子(gCO$_2$e/m^2)	材料消耗合计碳排放因子(kgCO$_2$e/m^2)
胶粘剂DTA砂浆	m^3	1.10E-03	–	–	–	–
干混抹灰砂浆 DP M20	m^3	1.86E-02	–	–	–	–
水	m^3	8.10E-03	–	–	–	–
白水泥	kg	2.59E+00	–	–	–	–
玻璃马赛克	m^2	1.03E+00	–	–	–	–

交通运输消耗量

材料名称	缺省 - 运输方式	缺省 - 运输距离(km)	材料运输CO$_2$碳排放因子(kgCO$_2$e/单位)	材料运输CH$_4$碳排放因子(gCO$_2$e/单位)	材料运输N$_2$O碳排放因子(gCO$_2$e/单位)	材料运输合计碳排放因子(kgCO$_2$e/单
胶粘剂DTA砂浆	GB 重型柴油货车运输（载重10t）	500	–	–	–	–
干混抹灰砂浆 DP M20	GB 重型柴油货车运输（载重10t）	500	–	–	–	–
白水泥	GB 重型柴油货车运输（载重10t）	500	–	–	–	–
玻璃马赛克	GB 轻型柴油货车运输（载重10t）	500	–	–	–	–

机械设备消耗量

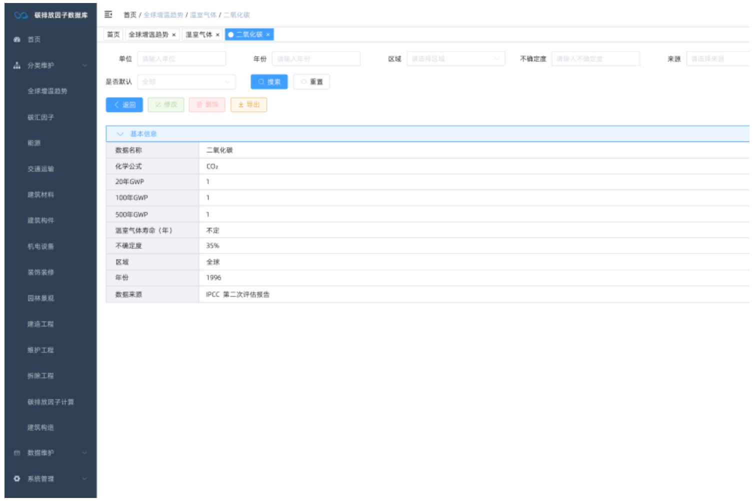
定额编号	机械设备	设备型号	能耗（kWh）	台班	CO$_2$面积碳排放因子(kgCO$_2$e/m^2)	CH$_4$面积碳排放因子(gCO$_2$e/m^2)	N$_2$O面积碳排放因子(gCO$_2$e/m^2)	面积合计碳排放因子(kgCO$_2$e/m^2)	CO$_2$重量碳排放因子(kgCO$_2$e/kg)	CH$_4$重量碳排放因子(gCO$_2$e/kg)	N$_2$O重量碳排放因子(gCO$_2$e/kg)
–	干混砂浆罐式搅拌机	–	–	3.10E-03	–	–	–	–	–	–	–

合计碳排放（B2 - B5）

	CO$_2$（kgCO$_2$e/单位）	CH$_4$（gCO$_2$e/单位）	N$_2$O（gCO$_2$e/单位）	合计（kgCO$_2$e/单位）
维护材料消耗量（面积）	–	–	–	–
维护材料消耗量（重量）	–	–	–	–
交通运输消耗量	–	–	–	–
机械设备消耗量	–	–	–	–
合计碳排放（B2 - B5）	–	–	–	–

Global warming trend

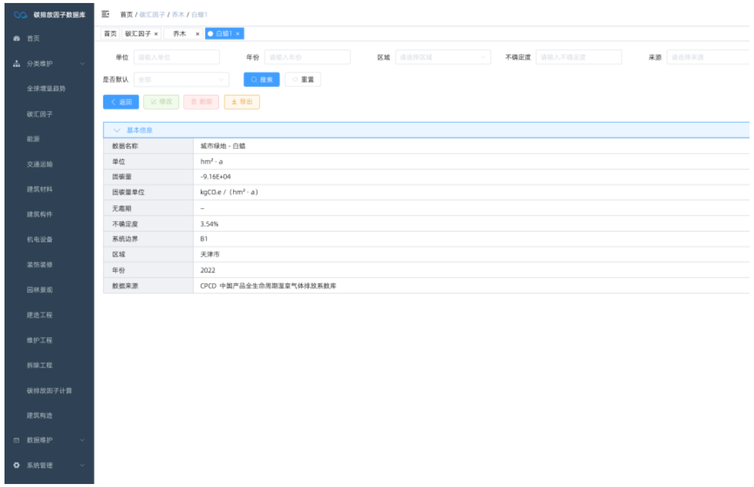
名称	化学公式	100年	温室气体寿命	不确定度	来源
▾ 全球增温趋势					
▾ 温室气体					
二氧化碳	CO_2	1	不定	35%	IPCC第二次评
甲烷	CH_4	21	12±3	35%	IPCC第二次评
氧化亚氮	N_2O	310	120	35%	IPCC第二次评
HFC-23（三氟甲烷）	CHF_3	11700	264	–	IPCC第二次评
HFC-32（二氟甲烷）	CH_2F_2	650	5.6	–	IPCC第二次评
HFC-41（一氟甲烷）	CH_3F	150	3.7	–	IPCC第二次评
HFC-43-10mee（1,1,1,2,2,3,4,5,5,5-十氟戊烷）	$C_5H_2F_{10}$	1300	17.1	–	IPCC第二次评
HFC-125（五氟乙烷）	C_2HF_5	2800	32.6	–	IPCC第二次评
HFC-134（1,1,2,2-四氟乙烷）	$C_2H_2F_4$	1000	10.6	–	IPCC第二次评
HFC-134a（1,1,1,2-四氟乙烷）	CH_2FCF_3	1300	14.6	–	IPCC第二次评
HFC-152a（1,1-二氟乙烷）	$C_2H_4F_2$	140	1.5	–	IPCC第二次评
HFC-143（1,1,2-三氟乙烷）	$C_2H_3F_3$	300	3.8	–	IPCC第二次评
HFC-143a（1,1,1-三氟乙烷）	$C_2H_3F_3$	3800	48.3	–	IPCC第二次评



数据名称	二氧化碳
化学公式	CO_2
20年GWP	1
100年GWP	1
500年GWP	1
温室气体寿命（年）	不定
不确定度	35%
区域	全球
年份	1996
数据来源	IPCC 第二次评估报告

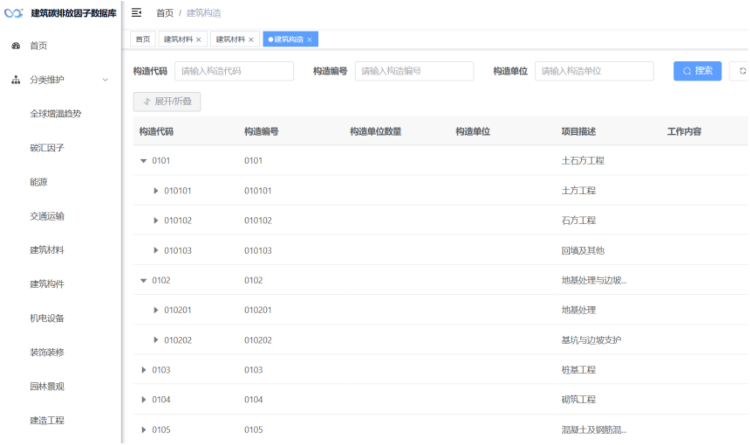
carbon sink factor

名称	单位	碳排放因子（$kgCO_2e$/单位）	年份	区域	无霜期	不确定度
▾ 碳汇因子						
▾ 乔木						
木材-杨树（木质素）	hm²·a	-338.48	2011	波兰	–	5.59%
杨树（波兰-土壤有机碳）	hm²·a	-31.07	2011	波兰	–	3.54%
杨树（波兰-土壤碳固存-61）	hm²·a	137.95	2011	波兰	–	3.54%
杨树（波兰-土壤碳固存-753）	hm²·a	-338.48	2011	波兰	–	3.54%
杨树（波兰-土壤碳固存-844）	hm²·a	-212.50	2011	波兰	–	3.54%
城市绿地 - 白蜡	hm²·a	-91600.00	2022	天津市	–	3.54%
城市绿地 - 垂柳	hm²·a	-87600.00	2022	天津市	–	3.54%
城市绿地 - 国槐	hm²·a	-31400.00	2022	天津市	–	3.54%
城市绿地 - 红叶李	hm²·a	-285000.00	2022	北京市	–	3.54%
城市绿地 - 栾树	hm²·a	-79800.00	2022	天津市	–	3.54%
城市绿地 - 毛白杨	hm²·a	-103400.00	2022	天津市	–	3.54%
城市绿地 - 悬铃木	hm²·a	-57200.00	2022	天津市	–	3.54%
城市绿地 - 榆树	hm²·a	-14800.00	2022	天津市	–	3.54%
城市绿地 - 海棠	hm²·a	-27200.00	2022	天津市	–	3.54%
香樟 - 《江苏省民用建筑碳排放计算导则（征求意见稿）》	m²·d	0.01	2023	中国江苏	–	7.07%



数据名称	城市绿地 - 白蜡
单位	hm²·a
固碳量	-9.16E+04
固碳量单位	$kgCO_2e$ /（hm²·a）
无霜期	–
不确定度	3.54%
系统边界	B1
区域	天津市
年份	2022
数据来源	CPCD 中国产品全生命周期温室气体排放系数库

building construction



构造代码	构造编号	构造单位数量	构造单位	项目描述	工作内容
0101	0101			土石方工程	
010101	010101			土方工程	
010102	010102			石方工程	
010103	010103			回填及其他	
0102	0102			地基处理与边坡...	
010201	010201			地基处理	
010202	010202			基坑与边坡支护	
0103	0103			桩基工程	
0104	0104			砌筑工程	
0105	0105			混凝土及钢筋混...	

A3. Glossary

CABR	China Academy of Building Research
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
DP	Demonstration Project
FHNW	University of Applied Sciences Northwestern Switzerland
HSLU	Lucerne University of Applied Sciences and Arts
HVAC	Heating, Ventilation, and Air Conditioning
LEED	Leadership in Energy and Environmental Design
Mohurd	Ministry of Housing and Urban-Rural Development (China)
NEZB	Net Zero Energy Building
PV	Photovoltaics
SDC	Swiss Agency for Development and Cooperation
SIA	Swiss Society of Engineers and Architects
Willers	Willers Jobst Engineering AG
ZEB	Zero Emission Buildings
ZHAW	Zurich University of Applied Sciences

ZEB
让我们共同打造气候中和的未来
Building a climate-neutral future together

中华人民共和国
住房和城乡建设部

IBE 环能科技

CABEE 中国建筑节能协会
CHINA ASSOCIATION OF BUILDING ENERGY EFFICIENCY

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

intep

skat_ Swiss Resource Centre and Consultancies for Development