Carbon emission accounting method of construction project during construction period

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Abstract. In the environmental impact assessment of construction projects, construction projects often involve a number of projects, and the construction period is complex, and there are many energy-saving and emission reduction links. Therefore, it is difficult to objectively and scientifically establish a set of energy-saving and emission reduction index system and accounting methods. The selection and quantification of the index system and accounting model are all technical difficulties. In this paper, the energy consumption and carbon emissions in the construction process of a project are calculated, and the internal and external carbon emissions are calculated respectively, which provides a basis for the subsequent energy conservation and emission reduction of the project.

Keywords: Carbon emissions, accounting model, energy conservation and emission reduction.

1. Classification of carbon emissions during the construction period of construction projects

The energy consumption, greenhouse gas emissions and pollutant emissions in the whole process of construction and operation of a project are divided into endogenous and exogenous [1,2].

Endogenous energy consumption, greenhouse gas emissions and pollutant emissions refer to the energy consumption, greenhouse gas emissions and pollutant emissions directly generated by the construction process itself, including only the actual energy consumption, greenhouse gas emissions and pollutant emissions, such as the energy materials burned by the construction machinery in the production and construction, such as steam (diesel) oil, coal, asphalt, etc. Emissions of carbon dioxide and carbon monoxide, sulfur dioxide, etc. Endogenous energy consumption, greenhouse gas emissions and pollutant emissions may also include energy consumption, greenhouse gas emissions and pollutant emissions changes caused by resource changes such as changes in the vegetation or water environment of the project itself, and energy consumption, greenhouse gas emissions and pollutant emissions changes caused by the life and production activities of construction personnel.

Endogenous energy consumption, greenhouse gas emissions and pollutant emissions do not include the energy consumption, greenhouse gas emissions and pollutant emissions carried out in the production process of various materials in the construction of the project, such as steel, cement, cable, steam (diesel) oil, coal, asphalt and other external industrial systems have generated energy consumption, greenhouse gas emissions and pollutant emissions in their production. This part of energy consumption, greenhouse gas emissions and pollutant emissions are exogenous energy consumption, greenhouse gas emissions and pollutant emissions.

The energy consumption, greenhouse gas emission and pollutant emission during the construction period are composed of endogenous and exogenous energy consumption, greenhouse gas emission and pollutant emission. The significance of endogenous and exogenous differentiation is that it can distinguish which sources of energy consumption, greenhouse gas emissions and pollutant emissions are really from the project, and it can be determined which industrial system production of energy consumption, greenhouse gas emissions and pollutant emissions are for the service of the project.

This paper takes the construction of a bridge project as an example to calculate the internal and external energy consumption and carbon emissions respectively, which provides data support for the subsequent energy conservation and emission reduction of the project.

2. Internal carbon emission accounting during the construction period

2.1 Internal accounting methods and basis

The internal accounting method and coefficient selection are explained as follows:

(1) The calculation coefficient is preferentially referred to the domestic and international standards that have been promulgated. In the absence of relevant accounting standards, accounting methods and parameters are selected after comprehensive analysis according to statistical yearbook and relevant literature.

(2) Comprehensive energy consumption accounting with reference to the General Principles for the Calculation of Comprehensive Energy Consumption (GB/ T2589-2008), all kinds of energy consumed in the construction process, including raw coal, standard coal, gasoline, diesel, heavy oil, electricity, etc., will be converted into standard coal.

(3) Carbon emissions were calculated using the emission coefficient method, with reference to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories 2019 Revised Edition [3-4], General Principles for the Calculation of Comprehensive Energy Consumption (GB/T 2589-2008) and the Guidelines for the preparation of Provincial Greenhouse gas Inventories (Climate [2011]1041), etc. This study mainly accounts for CO_2, and other greenhouse gas emissions are not included in the accounting object.

(4) The accounting of pollutant emissions adopts the material balance algorithm, and the accounting is carried out with reference to the Material Accounting Method for Air Pollutants Emitted by Fuel Combustion (Interim).

(5) The data of engineering activities mainly come from the preliminary design data of each project.

2.2 Calculation and analysis of internal energy consumption

The energy consumed in the construction process is mainly raw coal, standard coal, gasoline, diesel, heavy oil and electricity. The calculation formula is as follows:

$$N = \sum_{i=1}^{n} a_i N_i$$

N - Total energy consumption in construction, tce(ton of standard coal equivalent);
N_i - Class i energy consumption;
a_i - Discount coal coefficient for Class i energy, tce/t;
i - Class i energy.

The calculation of internal energy consumption in construction is shown in Table 1.

Table 1 Overall accounting of internal energy consumption of construction projects

Energy type	unit	Total quantity	standard coal coefficient	Energy consumption (tce)
Heavy oil	t	130.75	1.4286tce/t	186.79
Gasoline	t	26.87	1.4714tce/t	39.53
Diesel	t	4338.76	1.4571tce/t	6322.01
Raw coal	t	101.24	0.7143tce/t	72.32
Electricity	Ten thousand kilowatt-hours	1047.52	1.229tce/ Ten thousand kilowatt-hours	1287.40
Total				7908.04

2.3 Accounting and analysis of endogenous carbon emissions

This paper mainly accounts the carbon emissions of construction machinery burning energy materials in engineering production and construction. In addition, the electricity consumption of the

construction process does not directly emit greenhouse gases and pollutants, and is not included in the internal accounting. The calculation method is emission coefficient method. That is, the CO_2 emission coefficient is calculated first, and then the fuel consumption is multiplied by the carbon emission coefficient to obtain the CO_2 emission. The CO_2 emission coefficient is calculated as follows.

$$\beta_{CO2} = V \times C \times \eta \times 10^{-9} \times (44/12)$$

β_{CO2} -- CO_2 emission coefficient, $kgCO_2/kg$;
V -- average low calorific value of fuel, kJ/kg;
C -- carbon content per unit calorific value, tons of carbon /TJ;
η - carbon oxidation rate.

The internal carbon emission accounting of engineering construction is shown in Table 2. The largest CO_2 emission in engineering construction is diesel, about 13,500 tons.

Table 2 Calculation of total CO_2 emissions from internal sources of construction projects

Energy type	Total CO_2 emissions (t)	CO_2 emission coefficient (tCO_2/t)	Total CO_2 emissions (t)
Raw coal	101.24	1.90	192.36
Heavy oil	130.75	3.17	414.48
Gasoline	26.87	2.93	78.73
Diesel	4338.76	3.10	13450.16
total			14135.72

3. External carbon emission accounting during the construction period

3.1 External accounting methods and explanations

The calculation of exogenous energy saving and emission reduction in engineering construction is mainly aimed at the energy consumption, carbon emission and pollutants in the production process of construction materials. The selection of energy consumption or emission coefficient for the production of various materials needs to refer to existing standards and research literature, combined with industry investigation and consultation. In terms of building materials, domestic scholars have summarized low-carbon development strategies and measures for cement industry and steel industry [5-7]. In the field of construction, the low-carbon building concept of energy saving and emission reduction has gradually been put into engineering practice.

Exogenous energy saving and emission reduction accounting, the need to focus on and deal with the general issues include: classified statistics of materials, accounting coefficient selection, unit conversion and unification, and step accounting.

(1) Classification statistics of materials

Due to the complex and diverse types of materials invested in engineering construction, it is difficult to determine the calculation coefficient one by one at present. Therefore, it is necessary to classify the material input in the existing preliminary design report, classify and combine the materials whose physical composition is basically similar, and calculate according to the combined material categories.

(2) Selection or estimation of accounting coefficients

The accounting coefficient preferentially selects the relevant industry standards of the country, especially the cleaner production standards. The cleaner production standard gives three technical indicators of the cleaner production level in the production process of enterprises in various industries: the first level is the international advanced level of cleaner production; The second level is the advanced level of domestic cleaner production; The third level is the basic level of domestic cleaner

production. Taking into account the green procurement and energy-saving environmental protection demonstration requirements, the accounting coefficient preferentially selects the first-level production standard in the cleaner production standard.

For the material categories that have no national industry standards for the time being, it can be estimated by referring to the relevant literature and industry energy economic statistics. For the energy consumption structure of the material production process, in the absence of relevant data, the energy consumption structure of the corresponding industry can be temporarily referred to the "China Energy Statistical Yearbook".

For material categories that are lacking in national standards and related data, accounting coefficients can also be obtained through expert consultation.

(3) Unit conversion and unification

In the statistics of material input, the measurement standard and caliber are not uniform. In order to uniformly convert the material to a mass unit (ton) and count the material in volume units, the density needs to be determined; To count the number of materials, it is necessary to determine the standard quality of a single material; For materials that are counted in units of length, a standard mass per unit of length needs to be determined.

3.2 Calculation and analysis of external energy consumption

(1) Calculation coefficient of external energy consumption

The calculation coefficient of external energy consumption is mainly based on the General Principles of Comprehensive Energy Consumption Calculation and cleaner production standards. Different grades and specifications of material types, take the highest level of energy conservation and environmental protection production energy consumption coefficient for accounting. The energy consumption coefficient of exogenous production of primary energy is not the energy released by the combustion of primary energy, but the actual energy consumed in the process of producing primary energy. In the actual calculation, the energy consumption coefficient of primary energy can not be directly detected by the general principles of comprehensive energy consumption calculation and cleaner production standards, and it needs to be estimated by referring to relevant literature.

Among them, the selection of energy consumption coefficient of raw coal and petroleum processed products mainly refers to the "Energy Consumption of Major Energy-consuming Industrial Enterprises per Unit Product" released by Hebei Provincial Bureau of Statistics in 2011, and the power reference is to the statistical data of energy consumption of power generation on the official website of Southern Power Grid. For fresh water, the highest parameter in "Calculation Method and Limit of Comprehensive Energy Consumption per Unit Output of Tap Water" in "Tianjin Local Standard" was selected for calculation.

In the accounting, the engineering material units that can be accounted for are unified into tons, and the energy consumption is calculated according to the production energy consumption coefficient, and the unit is expressed by tons of standard coal (tce).

The calculation coefficients of external energy consumption are shown in Table 3.

Table 3 Energy consumption coefficient of construction materials production

Type	Production energy consumption	Basis
Raw coal	7.83kgce/t	《Energy Consumption per Unit Product of Major Energy-consuming Industrial Enterprises》
Standard coal	7.83kgce/t	《Energy Consumption per Unit Product of Major Energy-consuming Industrial Enterprises》
Gasoline	64.38 kgce/t	《Energy Consumption per Unit Product of Major Energy-consuming Industrial Enterprises》
Diesel	64.38 kgce/t	《Energy Consumption per Unit Product of Major Energy-consuming Industrial Enterprises》

Type	Production energy consumption	Basis
Electricity	198gce/（kw·h）	Southern Power Grid official website
water	294kgce/ten thousand tons	National Bureau of Statistics standard, oil refinery energy consumption calculation method
Oxygen	0.4kgce/m^3	comprehensive energy consumption calculation general average
Heavy oil	64.38 kgce/t	《Energy Consumption per Unit Product of Major Energy-consuming Industrial Enterprises》
Steel	385kgce/t	Cleaner Production Standard Steel Industry (Grade 1)
Rubber	50kgce/t	Energy consumption quota and calculation method (Hainan)
Acetylene	8.3143kgce/m^3	comprehensive energy consumption calculation general rule average
Paint	800kgce/t	Paint Unit Production comprehensive Energy consumption calculation method and limit (Tianjin)
Cement	93kgce/t	Cleaner Production Standard Cement Industry (Grade 1)

(2) Summary accounting of external energy consumption by material type

The quantity and energy consumption of different materials are summarized in Table 4. The total energy consumption of the overall project is 41,425.39 tons of standard coal.

Table 4 The quantity and energy consumption of different materials in the overall project

Type	Unit	Total quantity	Energy consumption coefficient	Energy consumption (tce)
Steel	t	73536.24	480kgce/t	35297.40
Rubber	t	51.96	50kgce/t	2.60
Iron	t	480.04	385kgce/t	184.82
Cement	t	38973.92	93kgce/t	3624.57
Heavy oil	t	130.76	64.38 kgce/t	8.42
Gasoline	t	26.87	64.38 kgce/t	1.73
Diesel	t	3181.50	64.38 kgce/t	204.83
Raw coal	t	101.24	7.83kgce/t	0.79
Electric	kw·h	10240000.00	198gce/（kw·h）	2031.43
Water	t	2279749.88	294kgce/ten thousand tons	67.02
Paint	t	0.07	800kgce/t	0.06
Oxygen	m^3	133.68	0.4kgce/m^3	0.19
Acetylene	m^3	58.12	8.3143kgce/m^3	1.53
total				41425.39

Through calculation, it is found that the building materials of external energy consumption of engineering construction mainly come from steel, accounting for 86% of the proportion. The second energy consumption is cement, the proportion of about 9%; The third is electricity, which is about 5%; The proportion of external energy consumption of other building materials is almost zero. It shows that the largest external energy consumption is steel, and other energy consumption is relatively small.

Therefore, in the management of energy conservation and emission reduction, for the external energy consumption of different materials, the amount of building material steel in the whole project should be saved under the premise of ensuring safety and quality, and the energy consumption should be reduced to the minimum.

3.3 Accounting and analysis of exogenous carbon emissions

Exogenous carbon emission is the carbon dioxide already emitted by the external production system of intermediate products such as building materials used in the construction process.

(1) Estimation model and carbon emission coefficient

$$C = \sum_{i=1}^{n}\sum_{j=1}^{m} C_{ij} = \sum_{i=1}^{n}\sum_{j=1}^{m} A_{ij} X_{ij}$$

C — carbon emissions during production, t;

C_{ij} — the carbon emissions of Class i materials of type j specification, t;

A_{ij} — the carbon emission coefficient of Class i engineering materials of type j specifications, t/ unit of engineering quantity;

X_{ij} — the engineering quantity of Class i material of type j specification;

I = 1, 2,... n, denotes the type of engineering material after classification;

J = 1, 2,... m, represents the different specifications, models, etc., of engineering materials in major categories.

The determination of carbon emission coefficient is mainly based on the methods recommended by the IPCC (United Nations Intergovernmental Panel on Climate Change), and reference to relevant research literature at home and abroad, similar engineering cases and research results of related projects.

The analysis results are summarized in Table 5.

Table 5 Carbon emission coefficients of major energy production

Energy	Carbon dioxide Emission coefficient (kgCO2/t)	Basis
Raw coal	37.60	《A Preliminary Study on Carbon Emission Accounting of Underground Mining Coal Mines》
Petroleum and Petrochemical	53.56	《Research on Carbon Emission Fluctuation and Low-carbon Strategy of China's Petroleum and Petrochemical Industry》
Cement	295.4	《Carbon Emission Analysis of Energy Consumption in Cement Production》
Electricity	0.68（tCO_2/mW·h）	China power grid in 2008 electricity emission factor table
Steel	1140	2009 data released by the American Iron and Steel Institute

(2) Aggregate accounting of exogenous carbon emissions by material type

Based on the summary accounting, the total carbon dioxide emission of different materials was 11,1170.63 tons.

Table 6 Calculation of total external carbon emissions from construction projects

Type	Unit	Total quantity	CO_2 emission coefficient (kgCO_2/t)	Total CO_2 emission (t)
Steel	t	73536.24	1140	83831.32
Iron	t	480.04	1140	547.25
Cement	t	38973.92	295.4	13248.82
Heavy oil	t	130.76	53.56	6390.95
Gasoline	t	26.87	53.56	1.44
Diesel	t	3181.50	53.56	170.40
Raw coal	t	101.24	37.6	3.81
Electricity	mW·h	10240000.00	680	6976.64
Total				111170.63

4. Conclusion and prospect

(1) In the environmental impact assessment of construction projects, construction projects often involve a number of projects, and the construction period is complex, and there are many energy-saving and emission reduction links. Therefore, it is difficult to objectively and scientifically establish a set of energy-saving and emission reduction index system and accounting methods, and the selection and quantification of the index system and accounting model are technical difficulties. There are many factors involved in energy conservation and emission reduction during the construction period, so it is very difficult to identify and regulate these links and factors, and it is more difficult to determine the energy conservation and emission reduction coefficient of these links and factors. This paper provides the basis of internal and external carbon emission accounting for reference.

(2) The determination of energy conservation and emission reduction evaluation indicators in project construction involves many factors, and the determination of energy conservation and emission reduction indicators needs to be combined with international practices, but also based on the characteristics of the project itself. The determination of the benchmark of energy saving and emission reduction calculation index also needs a certain methodology and reference system support, and should consider the improvement of the design time node, the comparison with the traditional scheme, the implementation of new measures, and the improvement on the basis of the current background value.

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