ISBN: 978-84-697-1815-5

The methodology and case study of "Standards for Measuring, Accounting and Reporting of Carbon Emission from Buildings"

Authors:
Zhang Peng[1]
Wang Yan[1, 2]

[1] China Architecture Design And Research Group, Beijing, China
[2] School of Environmental Science and Engineering, Tianjin University, Tianjing, China

Abstract:*The Chinese carbon emission accounting system development started initially and the application on building industry for carbon emission accounting standard is very few. This paper introduces a Chinese standard named "Standards for Measuring, Accounting and Reporting of Carbon Emission from Buildings", which is authorized by China Association for Engineering Construction Standardization (CECS) and funded by China Ministry of Science and Technology.*

The paper introduces the methodology proposed in the standard for data collection, accounting and reporting building carbon emissions. A case study in the life cycle carbon emissions of two residential buildings in southwest China, Chengdu, is developed.

The result of case study shows that the methodology proposed in the standard for accounting building carbon emissions is workable. Also, It can be used as an important tool for building carbon emissions assessment. Finally this paper provides some scientific technical measures of energy efficiency increase and emissions reduction.

Key Words: Methodology, Carbon Emission from Buildings, life cycle, energy efficiency

1 Introduction

Building industry contributes greatly to the social sustainable development. According to the data form UNEP, energy consumption of building industry is 40% of the total social energy consumption and 33% of the global CO_2 emission [1]. As the biggest developing country, resources and materials consumed by building construction in China is 40%～50%[2] of total domestic resources. Measured by Tsinghua University based on the energy consumption data (2000~2005) from National bureau of statistics of China, the energy consumption from production of building materials, building operation and logistics transportation account for 45% of total domestic energy consumption[3].

In the 12th Five-Years Plan, GHG emission control from industrial, building, transportation and agriculture is evidently indicated. The work plan of GHG emission control of 12th Five-Years Plan indicates that statistical accounting system of GHG emission should be setup immediately, in order to implement the emission goal of unit GDP carbon emission intensity of 2020 reducation of 40％～45％ of 2005.

ISBN: 978-84-697-1815-5

Based on the background, authorized by China Association for Engineering Construction Standardization (CECS), China Architecture Design and Research Group (CAG) developed a standard "Standards for Measuring, Accounting and Reporting of Carbon Emission from Buildings", which is also funded by China Ministry of Science and Technology. This standard is based on the Research and Demonstration of Key Technologies Integration in Measuring, Accounting and Reporting of Carbon Emission, and Low Carbon Design for Urban Buildings (2011BAJ07B02), which is one of the 7 topics of Research and Demonstration of Key Technologies Integration in Urban Low Carbon Development (2011BAJ07B00), a research project supported by the state in the 12th Five-years Plan. The paper introduces the main content of the standard, and a case study in the life cycle carbon emissions of two residential buildings (one of them is existing and another is a new building) in southwest China, Chengdu, is developed.

2 Background

The current carbon emission accounting method includes two types as follow:

(1) Green building assessment system

The typical assessment system include LEED of USA, BREEAM of UK, BEPAC of Canada, CASBEE of Japan, Green Star of Australia and Green Mark of Singapore.[4] Part of indicators from above-mentioned system can reflect carbon emission results in a range, but they only focus on the direct energy use of building operation. Carbon emission is not considered as a critical index in these assessment systems.

(2) Methodology of building carbon emission and carbon emission inventory development

The methodology is measuring activity data and emission factor related to carbon emission in buildings, accounting and verification of the GHG emission in the boundary and finally the building carbon emission inventory could be collected. The representative methodology and standards include "Common Carbon Metrics" from UNEP SBCI in 2009[1], "Guidelines to account for and report on greenhouse gas emissions and removals for buildings in Hong Kong" in 2010 authorized by Environmental Protection Department and Electrical and Mechanical Services Department of Hong Kong[5], also an international building carbon emission measurement standard is developing by ISO based on "Common Carbon Metrics".

3 Methodology and main content of the standard

3.1 Principle of application

3.1.1 The measuring, accounting and reporting of carbon emission from buildings shall cover the whole life cycle of buildings

At each stage of material production, building construction, operation and maintenance, demolishment and recycling, there are energy and materials consumption that lead to carbon

ISBN: 978-84-697-1815-5

emissions and impact on the natural environment. So the measuring, accounting and reporting of carbon emission from buildings shall cover the whole life cycle of buildings.

3.1.2 Measuring, accounting and reporting of carbon emission from buildings shall follow the principles of relevance, completeness, consistency, accuracy and transparency

"Relevance" means that the chosen boundary, materials, data and methods for quantifying carbon emission from buildings can appropriately reflect the situation of relevant carbon emissions from buildings and satisfy relevant requirements; "completeness" means that given the chosen building and measurement boundary, all information on carbon emission should be quantified and reported. Any exclusion needs to be justified; "consistency" means that consistent methodologies should be adopted to quantify and report carbon emission at various life cycle stages. Any changes to calculation scope, boundary or methods should be documented in the same way and recorded clearly; "accuracy" means that any data sources and calculation methodologies in respect of carbon emission from buildings shall be on an reliable and accurate basis; "transparency" means that any references to information on carbon emission from buildings should be reported in an adequate, sufficient and transparent manner.

3.2 Main content of the standard

3.2.1 Accounting model

Accounting model is based on the method of carbon emission factor, shown as formula (1)

$$E = \sum_{i=1}^{n} (AD_i \times EF_i)$$

(1)

In formula (1), E is building carbon emission of the GHG (tCO_2), AD_i is activity data of the i type of emission source, energy, resources and materials consumed, EF_i is carbon emission factor of the i type emission source.

Building carbon emissions in the whole life cycle are accounting with the formula (2)

$$E_{LC} = E_{SC} + E_{SG} + E_{YX} + E_{CJ} - E_{HS}$$

(2)

In formula (2), E_{LC} is carbon emission in the whole life stages of building (tCO_2), E_{SC} is carbon emission in the materials production stage (tCO_2), E_{SG} is carbon emission in the construction stage(tCO_2), E_{YX} is carbon emission in the operation and maintenance stage (tCO_2), E_{CJ} is carbon emission in the demolishment stage (tCO_2) and E_{HS} is the deduction amount of carbon emission in the recycle stage (tCO_2).

ISBN: 978-84-697-1815-5

3.2.2 Data measuring

Activity data (*AD*) can be collected and measured by meters, reviewing and analyzing documents or analysis and estimation according to the following rules:

(1) When the activity data can be automatically monitored, the method of monitoring instrument shall be adopted, to ensure the completeness, continuity and accuracy of the data;

(2) If the activity data cannot be automatically and continuously monitored, data shall be collected and measured by reviewing the technical documents, files, payment bills, financial reports and other documents of the engineering construction projects;

(3) If the activity data cannot be collected and measured through the aforementioned methods, the data shall be measured by analysis and estimation as per relevant formulas.

The common activity data measuring for building carbon emission accounting is shown as table1.

Table1 common activity data for building carbon emission accounting

different periods in the life cycle	unit process	activity data		
		material consumption	energy consumption	water consumption
material production	material production	●		
building construction	material transportation		●	
	operation of the construction machines		●	●
	onsite lighting and office activity		●	
operation and maintenance	operation of the equipment system		●	●
	material for maintenance and replacement	●		
	material transportation		●	
	activity for maintenance and replacement		●	●
demolishment	operation of demolishing machines		●	
	transportation of wastes		●	
recycling	recycle of buildings materials	●		

Carbon emission factor (*EF*) shall come from recognized and reliable source. Recently publish data is preferred. Before the establishment of a complete data base on carbon emission factors, the following sources are recommended for carbon emission factors::

ISBN: 978-84-697-1815-5

(1) Documents that are offically and consecutively published by authorized organizations;

(2) Research reports from certified academic research institutions;

(3) Statistics yearbooks and reports;

(4) Information on work flow process of factories.

The common carbon emission factors used for accounting building carbon emissions are collected in table2.

Table2 common carbon emission factors used for accounting building carbon emissions

materials					
materials	emission factor	source	materials	emission factor	source
ABS	17.984kgCO_2/kg	[6]	glass	2.79kgCO_2/kg	[9]
copper	7.924kgCO_2/kg	[7]	steel	3.55kgCO_2/kg	[10]
PVC	8.677kgCO_2/kg	[8]	concrete	0.157 kgCO_2/kg	[11]
PE	6.398kgCO_2/kg	[8]	mortar	0.282kgCO_2/kg	[12]
wood	0.053 kgCO_2/kg	[9]	brick	0.234kgCO_2/kg	[12]
energy and water					
Electricity	0.997 kgCO_2/kWh	[13]	water	0.3kgCO_2/m^3	[5]
Nature gas	2 kgCO_2/m^3	[14]	gasoline	kgCO_2/liter	[14]

3.2.3 Data reporting

The report on carbon emission from buildings shall include institution that develops the report, the functions and operating status of the buildings, the process of the calculation of the carbon emission of unit processes, carbon emission inventory of the buildings.

Table3 content of carbon emission reporting

	data reporting types		details
A	the section on the institution that develops the report	A-1	nature of the institution;
		A-2	purpose of the report and where does the task of measuring, accounting and reporting of carbon emission come from;
		A-3	contact person of the institution and people involved in the process.
B	section on the function and operating status of the buildings	B-1	location and scope of the building;
		B-2	type, function and purpose of the building;
		B-3	the period in the life cycle covered by the report;
		B-4	the unit processes of each period in the life cycle;
		B-5	operation year of the building.
C	section on carbon emission list of the buildings	C-1	carbon emission of different unit processes of the buildings;
		C-2	carbon emissions of different periods in the life cycle of the buildings;

ISBN: 978-84-697-1815-5

		C-3	the cumulative carbon emission of buildings till present day;
		C-4	total amount of carbon emission throughout the life cycle of buildings;
		C-5	ratio of carbon emission of different periods in the life cycle of buildings.

4 Case study of building carbon emission accounting

4.1 Basic information

The methodology of building carbon emission accounting proposed in the standard is applied and exemplified in 2 residential buildings located in Chengdu city (in southwest China, the capital of Sichuan Province). In order to guarantee the integrality of carbon emissions activity data, the two residential buildings are built by one company. One is an existing building which was built in 2003, another is a new building which was built in 2012. The basic information of them are summarized in Table4.

Table4 basic information of 2 residential buildings

basic information	existing building	new building
building area (m^2)	3153	7166
building structure	brick concrete structure	concrete frame shear wall structure
above-ground storey number	6	13
underground storey number	1	2
storey height (m)	3.25	3.25
building height (m)	19.5	42.25
building width (m)	12.6	15
building length (m)	38.8	55
service life span (year)	50	50

4.2 Results and discussion

4.2.1 Materials producing stage

The data of the consumption of 8 major materials are provided by the developer. Concrete, cement and brick are major materials in brick-concrete-structure existing building, accounting for 86.15% of the total materials consumption. Because the new building uses concrete frame shear wall structure, concrete, cement and steel are major materials used, accounting for 88.16% of the total.

Table5 consumption of materials

building material	existing building		new building	
	material weight	intensity of material consumption	material weight	intensity of material consumption

	(t)	(kg/m^2)	(t)	(kg/m^2)
cement	323.2	102.5	1620.2	226.1
steel	70.3	22.3	586.2	81.8
concrete	385.3	122.2	2682.9	374.4
PVC	29.3	9.3	25.1	3.51
glass	17.5	5.5	16.9	2.4
mortar	44.3	14.1	325.4	45.4
wood	0.95	0.3	4.78	0.67
brick	301.1	95.5	284.2	39.7
total	1171.95	371.69	5545.68	773.89

E_{SC} is calculated from the materials consumption. E_{SC} of the existing building amounts to 1171.95tCO_2. Cement, PVC and steel are major three parts of its carbon emission, accounting for 83.9% of the total. *Esc* of the new building amounts to 4482.43 tCO_2. Steel, cement and concrete are major three sources, accounting for 91.3%. The result shows that the carbon emission will be largely increased if the steel, PVC and cement are used. Using more bricks and woods will help reduce the carbon emission.

Table6 comparison of carbon emissions in materials producing stage

building material	existing building			new building		
	material weight (t)	carbon emission (tCO_2)	intensity of carbon emission (kgCO_2/m^2)	material weight (t)	carbon emission (tCO_2)	intensity of carbon emission (kgCO_2/m^2)
cement	323.2	317.4	100.67	1620.2	1591.0	222.02
steel	70.3	249.67	79.18	586.2	2081.0	290.40
concrete	385.3	60.5	19.19	2682.9	421.2	58.78
PVC	29.3	254.2	80.62	25.1	217.8	30.39
glass	17.5	13.3	4.22	16.9	12.8	1.79
mortar	44.3	12.5	3.96	325.4	91.8	12.81
wood	0.95	0.05	0.02	4.78	0.27	0.04
brick	301.1	70.5	22.36	284.2	66.5	9.28
total	1171.95	977.98	310.17	5545.68	4482.43	625.51

4.2.2 Construction stage

There are three sources of carbon emission in this stage. The first is the energy consumption when construction materials are transported from factories to construction sites. The second is energy and water consumption of the machines like tower cranes, elevators and concrete pumps. The last is the energy consumption of onsite lighting and office activities. All of the data above come from the reports of project developers. The water consumption's influence on carbon emission is ignored because the water consumption record of the construction cannot be collected.

ISBN: 978-84-697-1815-5

Table7 energy consumption of materials transportation

building material	existing building			new building		
	material weight (t)	distance of transportation (km)	energy consumption* （1）	material weight (t)	distance of transportation (km)	energy consumption （1）
cement	323.2	68	1736	1620.2	75	9600
steel	70.3	160	889	586.2	200	9262
concrete	385.3	17	517	2682.9	17	3603
PVC	29.3	1900	4398	25.1	1650	3272
glass	17.5	50	69	16.9	50	67
mortar	44.3	38	133	325.4	17	437
wood	0.95	90	7	4.78	90	34
brick	301.1	38	904	284.2	38	853
total			8653	total		27127

*: the average energy consumption of transportation is 7.6litre gasoline per 1000kg goods per kilometer (resource: 2013 China statistical yearbook)

Table8 energy consumption of construction machines

construction machine		existing building		new building	
machine type	power （kW）	running time (h)	power consumption (kWh)	running time (h)	power consumption (kWh)
tower crane	50	7520	376000	13210	660500
elevator	20	6832	136640	11420	228400
cutting machine	2.5	624	1560	1100	2750
reinforcing steel crooking machine	3	936	2808	1100	3300
reinforcing steel straightening machine	5.5	936	5148	1100	6050
reinforcing steel cutting machine	5.5	936	5148	1100	6050
electric welding machine	23.5	700	16450	772	18142
electro-slag welding machine	45	1530	68850	3680	165600
flash butt welder	100	1420	142000	3160	316000
concrete pump	75	470	35250	873	65475
concrete vibrator	1.1	948	1042.8	1396	1535.6
		total	790896.8	total	1473802.6

Table9 energy consumption of onsite lighting and office activities

construction machine		existing building		new construction building	
machine type	power (kW)	running time	power consumption	running time	power consumption

ISBN: 978-84-697-1815-5

		(h)	(kWh)	(h)	(kWh)
air conditioning	1.0	None use	None	1996	1996
lighting	0.04	17207	688	51229	2049
computer	0.3	8932	2680	11384	3415
		total	3368	total	7460

E_{SG} of the existing building in this stage amounts to 811.5 tCO_2, and the new building's amounts to 1538.8 tCO_2. As the new building used more materials, the carbon emissions of materials transportation are three times as much as that of the existing building, but the intensity of energy consumptions and carbon emissions of new building are effectively reduced by making a more scientific and reasonable construction plan. Its carbon emissions intensity is 214.74 $kgCO_2/m^2$, which is only 83.4% of the existing building.(Shown as the table10)

Table10 comparison of carbon emissions in construction stage

building material	existing building			new building		
	energy consumption	carbon emission (tCO_2)	intensity of carbon emission ($kgCO_2/m^2$)	energy consumption	carbon emission (tCO_2)	intensity of carbon emission ($kgCO_2/m^2$)
materials transportation	8653L	20	6.34	27127L	62	8.65
construction machine	790896.8kWh	788.5	250.08	14738.2.6kWh	1469.4	205.05
onsite lighting and office activity	3368kWh	3	0.95	7460 kWh	7.4	1.03
total	/	811.5	257.4	/	1538.8	214.74

4.2.3 Operation and maintenance stage

The sources of carbon emission in the operation and maintenance stage include energy and water consumption of the building in the 50 years operation period, materials used for maintenance, materials transporting, energy and water consumption of maintenance activities. The data of the energy and water consumption of the buildings is collected from the measuring meters. The existing building uses the average data of 2004 to 2013, and the new construction building uses the data of 2013.

Table11 energy and water consumption of building operation

building	electricity (kWh/a)	nature gas (m^3/a)	water (m^3/a)	record period
existing building	74671	8346	4042	2004-2013
new construction building	227957	22645	7754	2013

ISBN: 978-84-697-1815-5

Among the 8 materials listed above, PVC, glass and wood will be replaced for interior fitting out and exterior surface maintenance. Given the maintenance takes place every 15 years, the existing building will use 143.25t materials for maintenance in the 50-years operation period and another 2113L gasoline for transportation. The new building will use 140.34t materials and 2070L gasoline.

Table12 consumption of materials and transportation energy for maintenance activity

building	times of material replace	material weight (t)			Total (t)	energy consumption of materials transportation (l)
		PVC	glass	wood		
existing building	3	87.9	52.5	2.85	143.25	2113
new building	3	75.3	50.7	14.34	140.34	2070

The property management companies are usually responsible for the building's daily maintenance in China. To simplify the calculation, the property management company's energy and water consumption are taken as the energy consumption for maintenance activities in the cases, that is 5%, told by the managers of the two buildings, of the building's total energy and water consumption within a year.

Table13 energy and water consumption of maintenance activity

building	electricity (kWh/a)	gas (m^3/a)	water (m^3/a)
existing building	3733.55	417.3	202.1
new building	11397.85	1132.25	387.7

In the operation and maintenance stage, E_{YX} of existing building is 5656 tCO_2 in total with carbon emission intensity of 35.88 $kgCO_2/m^2 \cdot a$, and the new building is 21096 tCO_2 with carbon emission intensity of 58.87 $kgCO_2/m^2 \cdot a$. The major reason for the fact that the new building's carbon emission intensity is higher than the existing building's is every family in the new building installs household central air conditioning system while only a few families in the existing building install split air conditioner. As a result, the new building costs much more electricity.

Table14 comparison of carbon emissions in operation and maintenance stage

		existing building		new building	
		activity data	carbon emission in 50years(tCO_2)	activity data	carbon emission in 50years(tCO_2)
building operation	electricity(kWh/a)	74671	3722.35	227957	11363.66
	nature gas(m^3/a)	8346	834.60	22645	2264.50
	water (m^3/a)	4042	60.63	7754	116.31
material replace	PVC (t)	87.9	762.71	75.3	653.38
	galss (t)	52.5	39.90	50.7	38.53
	wood (t)	2.85	0.16	14.34	0.80

material transportation	gasoline (L)	2113	4.81	2070	4.71
maintenance activity	electricity(kWh/a)	3734	186.14	11398	568.19
	nature gas(m3/a)	417	41.70	1132	113.20
	water (m3/a)	202	3.03	388	5.82
total		/	5656.02	/	21095.76
intensity of carbon emission（$kgCO_2/m^2 \cdot a$）		/	35.88	/	58.87

4.2.4 Demolishment stage

The sources of carbon emission in the demolishment stage includes energy consumption of demolishing machine's and energy consumption of transporting waste from the demolishing site to landfill. The disposal of the waste is not considered in this paper. According to the life cycle assessment result of energy consumption for typical Chinese buildings[15], the average intensity of energy consumption in the demolishment stage is 107.7 kWh/m^2. Demolishing the existing building costs 339578 kWh and the new construction building costs 771778 kWh.

According to the energy consumption, E_{CJ} of existing building is 338.56 tCO_2 and the new construction building's is 769.46 tCO_2. The result reflects the scale difference of the two projects.

4.2.5 Recycle stage

Some materials can be recycled after demolishment, so the embodied carbon of these materials should be deducted from the total amount of carbon emission in a building's life cycle. According to the average recycle rate of the major materials, recyclable materials of the two buildings can be estimated (shown as the table15). The total amount of the recyclable materials of the existing building is 564.69t and the recovery rate is 48.2%. The total amount of the recyclable materials of the new construction building is 2681.46t and the recovery rate is 48.4%. In the recycle stage, E_{HS} of the existing building is 453.34 tCO_2 and the new construction building is 2652.56 tCO_2. From the life cycle perspective, recycling materials has a remarkable effect on saving energy and reducing carbon emission.

Table15 comparison of carbon emissions deduction in recycle stage

building material	recycle rate[16]	existing building		new building	
		recycle material weight（t）	carbon emission deduction (tCO_2)	recycle material weight(t)	carbon emission deduction (tCO_2)
cement	20%	64.64	63.48	324.04	318.21
steel	95%	66.785	237.09	556.89	1976.96
concrete	60%	231.18	36.30	1609.74	252.73
PVC	25%	7.325	63.56	6.275	54.45
glass	80%	14	10.64	13.52	10.28

ISBN: 978-84-697-1815-5

mortar	0%	0	0.00	0	0.00
wood	10%	0.095	0.01	0.478	0.03
brick	60%	180.66	42.27	170.52	39.90
total		564.69	453.34	2681.46	2652.56

4.2.6 Life cycle carbon emission inventory

The existing building will emit 7353.73 tCO_2 in its whole life cycle stages. And its carbon emission intensity is 46.65 $kgCO_2/m^2{\cdot}a$ in the 50-years operation period. The new building will emit 19336.64 tCO_2 in its whole life cycle stages with carbon emission intensity 53.97 $kgCO_2/m^2{\cdot}a$ in the 50-years operating period. In the building's life cycle, most of carbon is emitted in the maintenance stage. The existing building's carbon emission in the maintenance stage accounts for 72.4% percent of a life cycle amount and the new building's accounts for 68.8%.

Table16 life cycle carbon emission inventory

<table>
<tr><th rowspan="2">Different periods in the life cycle</th><th rowspan="2">unit process</th><th colspan="2">carbon emission（tCO_2）</th></tr>
<tr><th>existing building</th><th>new construction building</th></tr>
<tr><td>material production stage</td><td>material production</td><td>977.98</td><td>4482.43</td></tr>
<tr><td rowspan="3">building construction stage</td><td>material transportation</td><td>20</td><td>62</td></tr>
<tr><td>operation of the construction machines</td><td>811.5</td><td>1538.8</td></tr>
<tr><td>onsite lighting and office activity</td><td>3</td><td>7.4</td></tr>
<tr><td rowspan="4">operation and maintenance stage</td><td>building operation</td><td>4617.58</td><td>13744.47</td></tr>
<tr><td>material for maintenance and replacement</td><td>802.77</td><td>692.71</td></tr>
<tr><td>material transportation</td><td>4.81</td><td>4.71</td></tr>
<tr><td>activity for maintenance and replacement</td><td>230.87</td><td>687.21</td></tr>
<tr><td rowspan="2">demolishment stage</td><td>operation of demolishing machines</td><td rowspan="2">338.56</td><td rowspan="2">769.46</td></tr>
<tr><td>transportation of wastes</td></tr>
<tr><td>recycle stage</td><td>recycle of buildings materials</td><td>-453.34</td><td>-2652.55</td></tr>
<tr><td colspan="2">total</td><td>7353.73</td><td>19336.64</td></tr>
<tr><td colspan="2">Intensity of carbon emission in whole life cycle stages（$kgCO_2/m^2{\cdot}a$）</td><td>46.65</td><td>53.97</td></tr>
</table>

4.3 Measures for CO_2 emissions reduction

According to the result of the case study, the measures of reducing carbon emissions are proposed as follows.

(1) In the materials producing stage. Lighten the building's structure as much as possible. The lighter the structure is, the less the materials will be used. As a result, the carbon emission will be less. Use more high-recycle-rate materials like steels and bricks. Use more materials like woods and stones which could be processed easier. The materials that need more complicate processing techniques will cause more carbon emission.

(2) In the operation and maintenance stage. Improve the building envelope thermal performance and reduce the building's load of heating and cooling. Use more clean energy like solar and use less fossil energy. Use high-efficient air-conditioner, heating system and lighting system. Help people raise energy-saving awareness and develop habit of energy-saving and carbon-cutting.

(3) In the construction and demolishment stage. An industrial and standard constructing method should be employed to cut energy and resource consumption. Enhance the usage rate of the waste and old materials.

5 Conclusions

This paper introduces the methodology proposed in the "Standards for Measuring, Accounting and Reporting of Carbon Emission from Buildings" for data collection, accounting and reporting building carbon emissions, then an case study of two residential buildings is taken. The life cycle carbon emissions of the two residential buildings are estimated on the basis of consumed energy and resources at each stage. The life cycle carbon emission of the existing building is 7353.73 tCO_2, and the intensity of life cycle carbon emission is 46.65 $kgCO_2/m^2$•a (service life span is 50 year), the new construction building is 19336.64 tCO_2 and 53.97 $kgCO_2/m^2$•a.

The result of case study shows that the methodology proposed in the standard is workable, Also it is an effective tool for building designers and policy-makers to take much of the further balances between the life cycle carbon emission and value creation of a building.

6 References

[1] UNEP. SBCI. (2010). Common carbon metric-Protocol for measuring energy use and report greenhouse gas emissions from building operations[R].

[2] Wu Xin． (2005). The research of construction project environmental impact evaluation method[D] (in Chinese). Tsinghua University.

[3] Li Zhaojian, JianYi. (2006) The analysis of building energy consumption of China. Architectural Journal. (in Chinese), 2006(7): 30-33.

[4] S. Thomas Ng, Yuan Chen, James M.W. Wong (2013). Variability of building environmental assessment tools on evaluating carbon emissions[J]. Environmental impact assessment review, 32(1): 131-141.

ISBN: 978-84-697-1815-5

[5] EPD. EMSD. (2010) Guidelines to account for and report on greenhouse gas emissions and removals for buildings in Hong Kong[R].
[6] JiangJinlong, XuJincheng. (2006) Life cycle assessment of ABS plastic. Journal of ZhengZhou University. (in Chinese) 38(2):59-63.

[7] GuLijin. (2009) Life cycle environmental impact assessment of Chinese construction industry[D]. (in Chinese). Tsinghua University.

[8] ChenHong, HeWeichang, ShiFeng. (2004) Life cycle assessment of some typical polymers materials. Journal of Environmental Sciences. (in Chinese) 24(3): 545-549.

[9] ChenYousheng. (2002) Life cycle assessment on the reduction of carbon dioxide emission of buildings[D] (in Chinese). National Cheng Kung University.

[10] GongZhiqi. (2004) Quantitative assessment of the embodied environmental profile of building materials[D]. (in Chinese). Tsinghua University.

[11] ZhaoPing, TongJifeng, MaJuanrong.(2004) The research on the system of the building material environment load index and evaluate[J]. China Building Materials Science & Technology. (in Chinese) 2004(6): 4-10.

[12] LuoZhixing, YanLiu, LiuJiaping. (2011) Research on building materials carbon emission calculation method and emission reduction strategies[J]. Building Science. (in Chinese) 2011(4): 4-11.

[13]http://www.ccchina.gov.cn/archiver/cdmcn/UpFile/Files/Default/20130917081426863466.pdf. 2013 Baseline Emission Factors for Regional Power Grids in China

[14] IPCC. (2001) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories[R].

[15] CaiXiangrong, WangMinquan, FuBoquan. (2010) Analysis of residential building carbon emissions and measures of energy saving and emission reduction[J] Journal of Disaster Prevention and Mitigation Engineering. (in Chinese) 30(9): 428-431.

[16] LuKaian. (1999) Current situation of construction waste and comprehensive utilization in China[J]. Construction Technology. (in Chinese) 1999(5): 46-47.

Acknowledgement

The research in this paper is funded by China National "Twelfth Five-Years" S&T plan with project number of 2011BAJ07B02. Thinks to the special contribution from Prof. He Jianqing and Prof. Jin Ruidong. Thanks to Chengdu Jiaoda Real Estate Co.,Ltd. for providing primary data of the residential buildings in this paper.