

Application of Life Cycle Assessment into the Apartment Housing and Calculation of the Energy Consumption and CO₂ Emission

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Summary

The environment has played a key role to improve the living condition and develop the scientific industry. In building industries, we should consider the environment and mitigate the environmental affect. For mitigating its affect, various areas of building technologies have been developed and applied into the filed work. In addition, the process in applying into field would require to conduct the assessment of the environmental affect and improve its applied technology. A lot of assessment methods have been proposed in evaluating the building condition such as post-occupancy evaluation, life cycle management and life cycle assessment. Among these assessment methods, life cycle assessment is effectively utilized the environmental affect during the building life cycle.

Therefore, this paper aimed at analyzing the energy consumption and CO₂ emission during the building life cycle, using the life cycle assessment and application of the example in apartment housing. This study shows that the maintenance and the production of building materials stage shares most of the amount of the energy consumption and CO₂ emission and directly plays an important role to planning the building in terms of the life cycle. Second, the other stages bring about a very small amount. It is important to decide the building shape and contents to mitigate the environmental affect in terms of material, volume, the pattern of the energy use and others.

1. Introduction

1.1 Background and Objective

The building has a life cycle of construction, use and maintenance management phase and removal/dissolution phase. It consumes an energy and results into emit the carbon-dioxide to affect environment within building life cycle. Consequently, forecasting the environmental affect to mitigate the resource use, energy and an environmental contamination leads to develop technologies for the environmental preservation.

For these, it must be comprehensively evaluated and analyzed about the natural resources and energy which is used in the building life cycle in terms of the energy consumption, global warming potential and CO₂ emission.

Life Cycle Assessment is effectively

utilized to grasp the resources, an energy consumption and an environmental affect during the building life cycle. Results of LCA process could present an energy consumption and an environmental contaminant quantitatively at each life cycle phase.

In this paper, it aimed at analyzing the energy consumption and CO₂ emission, using the inventory analysis, survey-based data and literature review for the apartment housing situated in Seoul. The energy consumption and CO₂ emission would be calculated in unit scale. Results of this paper could be possible to provide the relatively environmental affect degree among various construction materials and building types.

1.2 research methodologies and contents

The building life cycle is divided at construction, maintenance and removal/demolition phase. In this paper, among the

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life cycle phases, it analyzed pointedly on the construction, management phase and removal dissolution phase. Other parts would be analyzed to utilize the literature review which shares low energy consumption and CO₂ emission.

The construction material is collected for an inventory analysis. The inventory analysis is divided with the survey-based and indirect estimate method. An indirect estimation would use the linkage of the industries in order to produce its material which is used the demand of the energy which is committed during the building life cycle

Table1. Analyzed building synopsis

contents				
site area	99,744 m ²			
floor	35 floor(3 floor basement)			
building area	59,061 m ²	building coverage	59%	
total floor area	upper ground total floor area	355,075 m ²	floor space index	355 %
	basement total floor area	82,654 m ²		
	total	437,729 m ²		
gardening	29,109 m ²	Num. of household		1,829

In this paper, it used input-output analysis and conducted the inventory analysis. The transportation and construction part would use the literature review which are published and reported in various data. The energy consumption quantity and CO₂ emission used at the heating, lighting and cook are based on the survey data. An energy sources are composed of the city gas and electronic power and a district heating. The maintenance part of repair and the removal phase are applied with the reported research results. The waste transportation phase is applied with the investigation data surveyed in the companies.

1.3 Research scope

In order to analyze the energy consumption and a CO₂ emission, it is necessary to divide the building life cycle into phase. The construction phase is divided at material production, transportation and construction phase. The scope of a material production phase set from the resources mining to manufacturing for the building components applied in the building.

The transportation phase set the material movement to the building site. A construction phase set from starting construction of the first building to the building completion.

In use and maintenance phase, it was divided at maintenance for repair and use for the electric power, heating and the city gas for heating, lighting and cooking. In maintenance phase, the electric power, fuel use and equipment are analyzed, which are used for repairing the building in compliance with a deterioration. The analytical scope of removal/disuse phase includes the disposal of waste and transportation to the burial. There is no recycle of construction waste.

2. Energy consumption and CO₂ emission

2.1 Construction phase

In order to calculate the energy consumption and CO₂ emission, it needs to set the affecting factors in construction phase. The construction phase is divided at material production, transportation and construction phase.

In construction phase, the energy consumption and CO₂ emission are shown in Table2. As shown in table2, a total energy consumption is 5,093.01MJ/ m², among which share the material production 4,790.05 MJ/ m² and the transportation 104.92MJ/ m² and construction 198.04MJ/ m². The material transportation appears with 104.92MJ/ m² and shares low in total amount.

Table2. Construction phase

	energy consumption (MJ/ m ²)	CO ₂ emission (kg-CO ₂ / m ²)
production phase	4,790.05	413.19
transportation phase	104.92	7.40
construction phase	198.04	12.15
total	5,093.01	432.74

The CO₂ emission shows in similar to the energy consumption tendency. Total CO₂ emission amount is 432.74 kg-CO₂/ m², and the material production shares all of the amount and its value is 413.19 kg-CO₂/ m² and materials transportation 7.40 kg-CO₂/ m², the construction part 12.15 kg-CO₂/ m².

2.2 Use and maintenance and management phase

1) heating, lighting and cooking, etc..

The energy consumption against the use part of heating and cooking and electric light is shown as Table3, which is calculated through data of the investigation. Electric power shares 117.68MJ/m², district heating 170.42MJ/m² and total value is 302.68MJ/(m² · yr)

Table3. Energy use of heating, district and city gas(MJ/m²)

Electric power	District heating	City gas	Total
117.68	170.42	14.58	302.68

The CO₂ emission could be calculated by the energy consumption multiplication with the carbon dioxide coefficient of discharge of each energy. The CO₂ emission in heating, lighting is shown as Table4. According to results, the electric power emits CO₂ in 15.81 kg-CO₂/m², which is higher than the any other parts. Total CO₂ emission would be presented with 27.22 kg-CO₂/m².

Table4. CO₂ emission in heating, lighting and cooking(kg-CO₂/(m² · yr))

electric power	district heating	city gas	total
15.81	10.60	0.81	27.22

2) maintenance for repair

The energy consumption and CO₂ emission in maintenance for repair could be calculated by using the repair quantity explained in the amount of the construction materials as well as the electric power and oil during the maintenance stage. But, the target building was completed in 2004 May and has not been repaired so far after constructed because the time elapse is too short. Therefore, we utilized the reported literature and analyzed the energy consumption and CO₂ emission.

The energy consumption for repair would be 6.27MJ/(m² · yr). In addition, the CO₂ emission is calculated about 0.75 kg-CO₂/(m² · yr). It summarized the energy consumption and CO₂ emission during the maintenance and management and is shown as Table5. The heating part is showing a highest level in the energy consumption sources and the value is 308.95MJ/(m² · yr). Moreover, the electric power part is showing a high level in the CO₂ emission parts and its value is 15.81 kg-CO₂/(m² · yr). Total CO₂ emission is 27.97 kg-CO₂/(m² · yr).

Table5. Energy consumption and CO₂ emission in maintenance for repair

		energy consumption (MJ/m ²)	CO ₂ emission (kg-CO ₂ /m ²)
use phase	electric power	117.68	15.81
	heating	170.42	10.60
	city gas	14.58	0.81
maintenance and management phase		6.27	0.75
Total		308.95	27.97

2.3 Removal and disuse transportation phase

1) Removal phase

The various equipment and materials are used in demolition of building. But it has not been able to get the enough data to analyze the removal phrase so far. Despite of these difficulties, we get an approach to reported literature to analyze the removal phrase and provide the energy consumption and CO₂ emission.

As a results of removal phrase, the energy consumption and CO₂ emission is so small, compared with other life cycle. Its value is 1.07MJ/m² and CO₂ emission appears with 0.07 kg-CO₂/m².

2) Waste transportation phase

The roughly unit data could be set through survey to company because the basic unit against a construction waste would not be provided. The transportation of the construction waste after removal is supposed to use the 16 ton-truck. The waste occurrence unit is shown as Table6.

Table6. Basic unit of construction waste

type	occurrence unit(m ³ /m ²)	type	occurrence unit(m ³ /m ²)
apartment	3.5	Villa	4.0
shopping center	3.3	Hotel	5.0

Using the contents in Table6, it could conduct the energy consumption and CO₂ emission in construction waste transportation

i) waste quantity

$$3.5 \text{ m}^3/\text{m}^2 \times 437,729 \text{ m}^2 = 1,532,051.5 \text{ m}^3$$

ii) Transportation vehicle number

The transportation is supposed to use 16ton-truck and its total carrying capacity is 20 ton. Therefore, transportation vehicle of the construction waste corresponds to total 76,602 vehicles.

$$1,532,051.5 \text{ m}^3 / 20 \text{ m}^3 = 76,602$$

iii) The energy consumption in transportation distance and light oil use

The transportation distance is supposed in 20 km one way and its carrying capacity is 100%. Contrary, the back-to-site is supposed to half of the one-way. The fuel ratio of the truck did with 2.74 km/l. Consequently, it calculates the energy consumption in light oil use and these results are as follows.

a) one-way

- Total transportation distance :
 $20 \text{ km/vehicle} \times 76,602 \text{ vehicle} = 1,532,051 \text{ km}$
- Light oil consuming quantity in fuel ratio :
 $1,532,051 \text{ km} \div 2.74 \text{ km/l} = 559,142.8 \text{ l}$
- Total energy consumption calorie :
 $559,142.8 \text{ l} \times 9.2 \text{ MJ/l} \times 4.196 \text{ J/cal} = 21,584,702.14 \text{ MJ}$

b) back-to-site

The Back-to-site is supposed to a half of the one-way and consumes the energy a half of the one-way. Consequently, the energy consumption quantity could be gotten at 10,792,351.57MJ.

c) Energy consumption in transportation

The energy consumption in transportation could be summed at 32,377,054.71MJ both one-way and back-to site. it gets the unit data of the energy in 73.97MJ/m³.

iv) CO₂ emission

The CO₂ emission in transportation would be calculated to use the reported data. CO₂ emission, resulted from the energy consumption could be calculated with the CO₂ emission unit by the energy calorie.

a) one-way : Distance 20 km to waste disposal place

- 1 carbon-dioxide : $16 \text{ ton} \times 6.30 \times 10^{-2} \text{ kg-CO}_2 / (\text{ton} \cdot \text{km}) \times 20 \text{ km} = 2.016 \text{ kg-CO}_2$
- Total carbon-dioxide : $2.016 \text{ kg-CO}_2 / \text{vehicle} \times 76,602 \text{ vehicle} = 154,430 \text{ kg-CO}_2$

b) back-to-site

The CO₂ emission is 77,215.39 kg-CO₂. an half of the one-way value

c) CO₂ emission in transportation

The carbon dioxide inn transportation could be calculated at 231,645.39 kg-CO₂.

When this value is divided by the total floor area, it results at 0.53 kg-CO₂/m².

The summarization of the removal and waste transportation is shown in Table7. The waste transportation is 73.97MJ/m³ and it is highly level compared with removal phrase. The CO₂ emission is showing the tendency which is similar to the energy.

Table7. removal and disuse phase

	energy consumption (MJ/m ³)	CO ₂ emission (kg-CO ₂ /m ²)
Removal phase	1.07	0.07
Disposal phrase	73.97	0.53
Total	75.04	0.60

3. Conclusion and the further study

The building has life cycle of construction, use and maintenance management phase, removal/demolition phase. It consumes an energy and emits CO₂ in building life cycle, which affects the environment preservation.

In this paper, it aimed at analyze the energy consumption and CO₂ emission during the building life cycle, focused on the apartment housing situated on the Kyunggi province.

Results of this study are summarized as follows. First, the energy consumption of the construction phase is 5,093.01MJ/m². Specially, the energy consumption of the construction materials shares the 4,790.05MJ/m².

The CO₂ emission of the construction phase appears with 432.74 kg-CO₂/m². The CO₂ emission of the material production appears with 413.19 kg-CO₂/m². This is higher than any other part within the construction stage.

Results of this study show that it is important to select the building material which is low embodied energy and low emitted in the construction stage.

Table8. summary of the energy consumption and CO₂ in life cycle

		energy consumption (MJ/m ²)	CO ₂ emission (kg-CO ₂ /m ²)
construction stage	Product ion phase	4,790.05MJ / m ²	413.19 kg-CO ₂ / m ²
	Transp ortation phase	104.92MJ/ m ²	7.40 kg-CO ₂ / m ²
	Constru	198.04MJ/	12.15 kg-

	ction phase	m ²	CO ₂ / m ²
	Total	5,093.01MJ / m ²	432.74 kg-CO ₂ / m ²
Use/ mainten ance and managem ent stage	Electric power	117.68MJ/(m ² · yr)	15.81 kg-CO ₂ /(m ² · yr)
	District heating	170.42MJ/m ² · year	10.60 kg-CO ₂ /(m ² · yr)
	City g as	14.58MJ/m ² · year	0.81 kg-CO ₂ /(m ² · yr)
	maintenance and managem ent	6.27MJ/m ² · year	0.75 kg-CO ₂ /(m ² · yr)
	Total	308.95MJ/m ² · year	27.97 kg-CO ₂ /(m ² · yr)
Removal/ demolition stage	Removal phase	1.07MJ/m ²	0.07 kg-CO ₂ /m ²
	Disuse phase	73.97MJ/m ²	0.53 kg-CO ₂ /m ²
	Total	75.04MJ/m ²	0.60 kg-CO ₂ /m ²

Second, the maintenance for repair appears low level in the energy consumption and CO₂ emission, compared with the construction stage.

The energy consumption and CO₂ emission in the maintenance for repair appears with 6.27MJ/(m² · yr), which is lower than the use phase including the heating, lighting and cooking. The energy consumption in electric power appears with 170.42MJ/(m² · yr), city gases appearing with 14.58MJ/(m² · yr).

The CO₂ emission has a tendency similar to the energy pattern. Total CO₂ emission appears with 27.97 kg-CO₂/(m² · yr) and the portion of the repair phase appears 0.75 kg-CO₂/(m² · yr). The value of the electric power appears with 15.81 kg-CO₂/(m² · yr), the district heating is of 10.60 kg-CO₂/(m² · yr). These results show that it is important to control the heating, lighting and cooking and shares almost of the value.

Third, total energy in removal/demolition appears at 75.04MJ/m². The transportation phase shows in 73.97MJ/m² and shares the portion of this value. In terms of the CO₂ emission, Total value appears at 0.60 kg-CO₂/m² and the waste transportation shares 0.53 kg-CO₂/m².

The building interacts with the environment. Such a inter-dependence would mitigate the environmental affect and get an new approach to design building.

Researches like this study will provide the selection guide of the energy and material and the control method to mitigate the

CO₂emission. In addition, it should provide the methodologies to diminish the environmental affect from the planning & design.

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