KIEAE Journal
Vol. 14 No. 1 Feb. 2014, pp.49-57, pISSN 1598-3730, eISSN 2288-4823
http://dx.doi.org/10.12813/kieae.2014.14.1.049

# Study on the introduction and assessment of the Life Cycle Carbon Emissions in Office Buildings

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**Abstract**

Global warming has become a major issue all over the world. Noting the carbon dioxide emissions as a main contributor to global warming, we studied on the methods to reduce the life cycle building carbon emissions. Green Building Certification Criteria(GBCC) has been implemented since 2002 in Korea, but it doesn't estimate the quantities of the $CO_2$ emissions. Therefore, we studied the ways to implement the $CO_2$ emissions in quantity to GBCC.

We select a government building which was rated excellent by the GBCC. This office building was regarded to excellent building by GBCC but not good for energy consumption. It was found energy glutton buildings for research by the Ministry of Public Administration and Security in 2010. This part of GBCC is need to be improved..

Also LCA (Life Cycle assessment) was carried out to estimate on carbon footprint on this office building. So we need to implementing quantitative evaluation on the amount of carbon emissions by GBCC. And it is possible to implementing quantitative evaluation on the amount of carbon emissions.

Through this study, we expect that quantitative assessment of life cycle carbon emissions of buildings by the GBCC. Also expect to reduce the carbon emissions of the building by improving the GBCC.

Keywords : Green building, Green Building Certification Criteria(GBCC), Office building, Life Cycle, Carbon Emission

## 1. Introduction

### 1.1. Study background and purpose

With the continuation potential is being raised as an issue for the alternative solution methods of global warming, the carbon emissions are being noted as the direct cause for the global warming. Various strategies are being studied in multiple aspects to reduce the buildings' life cycle carbon emissions.

Diverse systems are introduced domestically for its realization, of which the green building approval system is being implemented in 7 different use categories including the office buildings. Among them the office building cases are 311(16.51%) cases out of pre-approval 1,884 cases, 137 cases(12.74%) out of the approved 1,075 cases; they are showing relatively small ratios compared to the community residences or school facilities. For the lately modified green buildings and their related systems, the control for the office buildings beyond a certain size are under growing regulations, while the larger sized office buildings are to pass the green building approval.

However, most office buildings approved as the green buildings are noted for its excessive consumption, whose carbon emission level is also presumed high. However, there are no quantitative evaluation items prepared for the carbon emissions and not enough evaluation strategies as the approval standards for the present green buildings. And not enough precedence studies to evaluate the office buildings' life cycle carbon emissions.

Thus, we realized the necessity of this study and approached with extracting the itemized preponderance through the detailed and itemized analysis of the green building approval performances, to analyze the carbon emissions related items within the approval system, ultimately to examine the current systems' innate problems. The study purpose is to propose the assessment and the necessity to introduce the green building approval system for the life cycle carbon emissions of the representative office buildings through quantitative evaluation.

### 1.2. study method and range

We analyzed the approval performances of the green building approval systems that are currently implemented domestically, examining the office buildings' current conditions of the green building approval. Also, among

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the respective detailed standards of the green building approval standards, we examined and analyzed the carbon emission life cycle evaluation and its related evaluation items. We investigated the energy consumption reality of the major office buildings in the operation stage and analyzed the current conditions and the problems of the office buildings' energy consumption, with S city hall in Kyunggi province in particular, which is currently being noted for its energy consumption related issues; and examined the evaluation results of the green building approval and implemented the life cycle carbon emissions assesment.

### 1.3. related precedence study

Yu, Su-hoon and one other (2002) conducted a study on the evaluation categorization system and evaluation item development for the office buildings' green propensity assesment..[1)]

Chung, Young-hwang and 3 others(2007) conducted a study on the evaluation items for the office buildings through the green building approval cases..[2)]

Mun, Misun and 3 others (2012) conducted a study on the energy sector improvement strategies of the office green building approval system. They analyzed the energy performance index achieved points and the renewable energy installation ratio with the office buildings as the subjects to evaluate their energy sectors and to propose the improvement strategies for the green building approval energy sector.[3)]

Likewise, the related precedence study has pointed out the different characteristics between the big office buildings and the general office buildings and the necessity for their improvement, but not for its carbon emissions related issues. Also, there are virtually no theories on the quantitative assessment methods for the building carbon emissions and their related precedence studies.

## 2. The current approval condition analysis for the office buildings as green buildings

### 2.1. The current use approval condition analysis before the green building approval system

There are 2,959 building evaluation approval cases in total from 2003 to August, 2012, through the green building approval system, with 1,884 pre-approval cases and 1,075 approved cases. In Fig. 1 and Fig. 2, the office buildings are 16.51% (311 cases) in the pre-approval stage and 12.74% (137) cases in the approval stage.[4)]

### 2.2. The current condition analysis and review in the office building green approval

Among the existing approval grades, the best grades, [5)], the current approval grades [6)] the number of the best (green grade1) and 2nd best (green grade 2) grade approval cases, among the pre-approval buildings 109 cases out of the grade identifiable[7)] 284 cases, 38.38%, among the approval buildings 36 cases out of the grade identifiable 121 cases, 29.75%.

As in Fig. 3 and Fig. 4, the green in approval cases are growing every year, for which there are clearly shown growing approval cases of the gross building area 30,000㎡ and beyond: in the pre-approval stage 36.27%, in the approval stage 48.76%.

For the past 5 years big office buildings approval cases are in growing notwithstanding the construction repression.

This is because the approval process for the big office buildings are institutionally obligated. Among the office buildings for which per sector evaluation scores are identifiable, there are approval 136 cases in the pre-approval stage and the approval stage in 2011,

per sector is shown in Fig 6, 88 cases in the pre-approval stage and the approval stage.

As we can see in the Fig. 5. 2006 approval standard office building approval average score, in the items other than the land use sector and the ecological environment sector, the average scores are spread evenly. The land use sector and the ecological environment sector do not reach 50% in the sector score ratio achieved. In the Fig. 6. 2010 approval standard office building approval score average shows relatively high average scores in the traffic sector, material and resources sector, energy sector, interior environment sector but still low in the land use sector and the ecological environment sector. We can see the preponderance even severer than before. The major scores per approval sector are in general focused on the sector with low construction cost.

1) Yoo, S.H, Cho, D.W., A Study on the Development of Category and Items of Environmental Assessment Method for Office Building, 2002.10
2) Jeong, Y.K., Lee. S,M., Park S,D. and Choi, M.H., An Analysis of Assessment Criteria from Certified Green Office Buildings, 2007.06
3) Moon, M,S, Park S,D, Lee, J. S., Tae, C. S., A Study on the Improvement of Energy Related Assessment Method in the Green Building Certification Criteria for Office Buildings , AIK Journal, 2012.12
4) G-SEED System, http://greenbuilding.re.kr Green building approval building current condition information2012.08
5) G-SEED standard [*8], 2002~2009, 1st grade above 85, 2nd grade above 65.
6) G-SEED [*9], 2010~present, 1st grade (Green grade 1) above 80, 2nd grade (Green grade 2) above 70, good (Green grade 3) above 60, general (Green grade 4) above 50.
7) 27 cases out of 311 pre-approval cases, and, 16 cases out of 137 approval couldn't be confirmed for the approval grade.

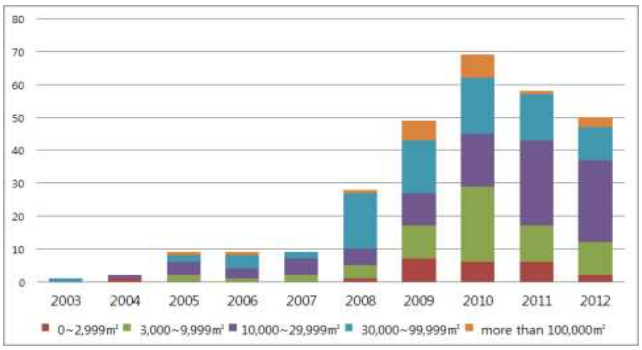


*Fig. 3. By year of commercial buildings, pre-certification number of different scale environment architecture*

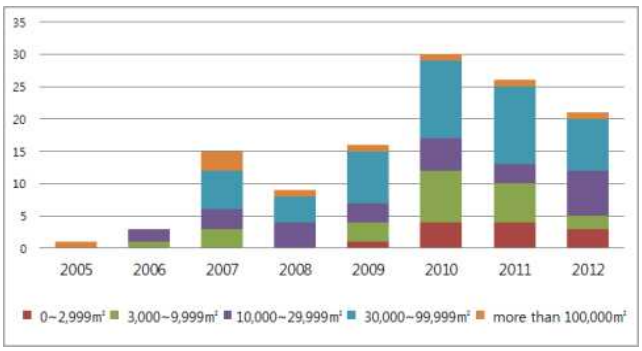


*Fig. 4. By year of commercial buildings, certification number this scale different environment architecture*

Also, the degrees of unequal distribution propensity per item can be confirmed in Fig. 7 per item average and standard deviation. Fig. 7 shows the result for the 2010 office building approval standard 88 cases based on the approval scores. As we can see in Fig. 7, the standard deviation values that achieved the relatively high scores per item show the relatively lower values, which exemplifies the items' average achieved scores' preponderance ; the standard deviation values that achieved the relatively low scores per item show the relatively lower values, which exemplifies the items' average achieved scores' preponderance.

The number and the size of the green approval

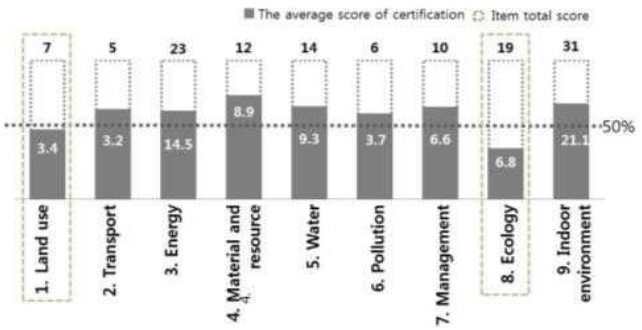


*Fig. 5. Certification standards of 2006, the average score of authentication of commercial buildings*

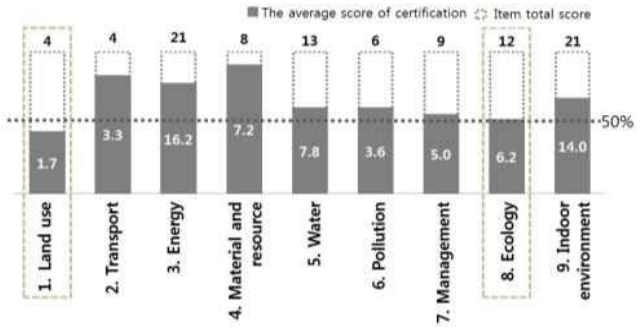


*Fig. 6. Certification standards of 2010, the average score of authentication of commercial buildings*

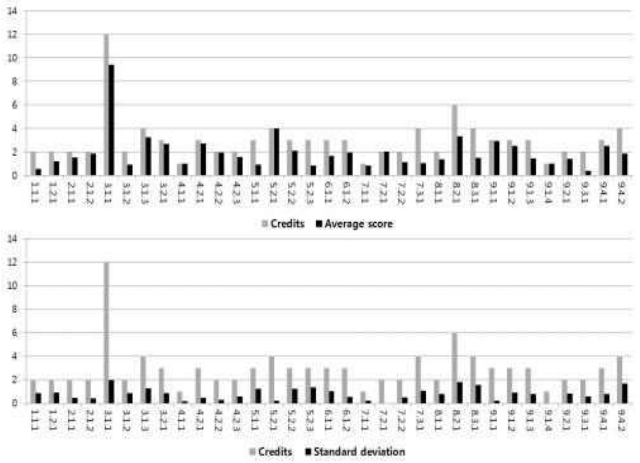


*Fig. 7. Certification standards of 2010, Mean and standard deviation scores of itemized*

registration cases of the office buildings are increasing. However, according to the current approval standard, there is a strong propensity shown that they only intend to get the approval grade by achieving the necessary scores only, but there is no way of knowing for the approval offices, implementers, and the users, about the energy consumption and carbon dioxide exhaust reduction effects.

## 3. The carbon emissions evaluation method of the office buildings

### 3.1. The carbon emissions evaluation methods and the introduction background

Among the green building evaluation approval systems, LEED in the U.S., BREEAM in U.K., CASBEE in Japan, SB-Tool in Europe, all include the carbon related evaluation items. The global efforts are increasingly stressing on the carbon related evaluation either including the life cycle evaluation or fortifying the quantitative evaluation.

In ISO/TS 21929-1 Framework, they define the building

 

with continuation potential in the environmental, social, and economical aspects, and emphasize the Life cycle analysis in the index process. In ISO21929-1 as the representative quotients of the environmental index, there are Environmental aspects, total $CO_2$ emission, $CO_2$ equivalents, public transportation, etc.

In the UNEP lead common carbon metrics, the global standards are defined on the life cycle carbon emissions evaluation, and the life cycle evaluations are proposed in the following 5 sectors in the big framework of environmental footprint.

- Energy use
- Material use
- Solid waste
- Water use
- Land use

### 3.2. The carbon emissions related detailed item analysis of the office building green building approval

In the current green building approval system, among the office building approval evaluation items the carbon emissions related evaluation items are shown in Table 1. The evaluation items in the 2006 approval standard are analyzed.

○ Energy consumption: the carbon emission and related evaluation items in the energy consumption sector are 4 items in total, with the related item score 26, and the average 16.06. (score achievement ratio 61.8%)

○ Material production : the carbon emission and related evaluation items in the material production sector are 2 items in total, with the related item score 3, and the average 2.62.

○ Water resources : the carbon emission and related evaluation items in the water resources sector are 2 items in total, with the related item score 7 (additive item 4 points included), and the average 3.58.

○ carbon cancelling index : the carbon emission and related evaluation items in the carbon cancelling index sector are 2 items in total, with the related item score 9, and the average 4.63. In the 2006 approval standard, the carbon emission related item score is 45, with the achievement scores being carbon emission related total 45 in total and the average 26.89.

Currently there are no carbon emission related evaluation items in the solid waste sector. Table1 shows the carbon emission related detailed items within the

*Table. 1. Carbon emission criteria in GBCC*

| Category | Qualification standard 2006 | | | | Evaluation method |
|---|---|---|---|---|---|
| | Sub-category | | Credits | Obtain score | |
| Energy use | 3.1.1 | Energy performance | 15 | 9.19 | Assess based on “Energy Performance Index (EPI)” of “Energy Saving Design Standard (MLTM)” or “Buildings’ Energy Efficiency Certification” |
| | 3.2.2 | Energy saving of lights | 6 | 3.87 | Artificial Lighting Energy Saving by lightning density and lightning method |
| | 6.1.1 | Reducing $CO_2$ emission | 3 | 1.57 | Installation of system to reduce $CO_2$ emission |
| | 9.2.1 | Auto temperature adjusting device for each room | 2 | 1.43 | Installation of device which can control room temperature in each zone or room, or linked to home automation system |
| Subtotal | | | 26 | 16.06 | |
| Material resource | 4.2.2 | Use of eco-friendly certified products | 3 | 2.62 | Use of Eco-Label or GR mark certified products |
| Subtotal | | | 3 | 2.62 | |
| Water | 5.2.2 | Rain water harvesting | 3 | 2.05 | Provision of facilities enabling reuse of rain water for agriculture |
| | 5.2.3 | Grey water facility | 4 | 1.53 | Grey water facilities enabling re-use for agriculture |
| Subtotal | | | 7 | 3.58 | |
| Carbon offset | 3.2.1 | Use of new/renewable energy | 2 | 1.27 | Building’s durability under odrinary management condition |
| | 8.1.1 | Ratio of ecological area | 7 | 3.36 | Assess based on the area calculated by separating spaces with different ecological function, applying weight, and averaging |
| Subtotal | | | 9 | 4.63 | |
| Total | | | 45 | 26.89 | |

approval system, with the scoring ratio about 60%. However, there is no knowing whether the scoring within the energy sector in such green building approval system relates to the carbon emissions related items scoring.

### 3.3. The carbon emissions related item analysis result

Also, there are carbon emission related evaluation items in the green building approval system but the carbon emission reduction methods are not showing up in surface. Although there exist the carbon emission related evaluation items, the quantitative evaluation items of the carbon emissions are nonexistent. With the evaluation score alone, there is no knowing in the carbon emissions amount, big or small, in the current green building approval system.

## 4. The carbon emissions case evaluation of the office buildings

### 4.1. The government office buildings energy use reality result analysis

In 2010 the Ministry of Public Administration and Security and the Ministry of Knowledge Economy conducted a study analysis on the energy use in the 246 self-governing body offices, analyzing 2009 use condition with the resulting energy consumption per unit area as follows in Table. 2:[8)]

Among them S-city hall building consumed the 2nd most per area used amount energy, which achieved the 2nd best grade in 2004 green building pre-approval; and the K district office marked the 4th in per area used amount energy consumption, but achieved the 2nd best grade in 2005 green building pre-approval.

Table. 3. S-city hall building was assessed below standard in the building energy efficiency grade and achieved in 2009 green building 2nd best grade.

Likewise, some buildings, although achieving the 2nd best grade in the green building approval system, are assessed as energy over-consumption buildings in the operation stage energy consumption reality investigation. This means that there is some revision to be made in the green building approval system operation stage energy consumption evaluation, also becoming a factor to lower the credibility in the green building approval system. We need a quantitative evaluation item to identify the energy use amount with.

We intend to select a representative case public government building in energy over-consumption, and at the same time achieved the top grades in the green approval grades, to evaluate the carbon emissions quantitative analysis.

*Table. 2. Energy Glutton Buildings of local government per unit area*

| Ranking | Usage per unit area(kgoe/㎡) | | | |
|---|---|---|---|---|
| | Local government office(year completed) | 2008 | 2009 | Fluctuation |
| | National average | 29.4 | 30.4 | 3.1 |
| <05~07year 12 office> | | 29.1 | 28.3 | ▽2.5 |
| 1 | Y city hall('05) | 39.0 | 36.7 | ▽5.9 |
| 2 | s city hall('07) | 39.3 | 35.5 | ▽9.6 |
| 3 | C district office('06) | 33.3 | 35.1 | 5.4 |
| 4 | K gu office('07) | 33.3 | 34.4 | 3.3 |
| 5 | C city hall('05) | 30.9 | 32.2 | 1.3 |

*Table. 3. Buildings' Energy Efficiency Certification[9)]*

| Local government office | Evaluation of building | Per unit area Primary energy requirements (kWh/㎡) |
|---|---|---|
| Y city hall | Outside judgment (Less than 5 Rating) | 791.3 |
| S city hall | Outside judgment (Less than 5 Rating) | 603.3 |
| C city hall | 4 Rating | 422.2 |

### 4.2. The representative case selection

S-city hall building in Kyunggido was built in October, 2009. It achieved the 2nd best grade in Nov. 2009 in the green building approval system. However, as in Table. 3, the 1st stage per area energy consumption amount is 603.3kWh/㎡, hardly reaching the building's energy efficiency grade 5 grade. Also, the carbon emission related item scored 31.36 out of total score 45, with the ratio 69.7% . The carbon emissions related evaluation item scores are shown in Table 5. The operation stage energy consumption related sector is the energy sector with the total 3 evaluation items. S-city hall building scores per item are shown in Table 6.

- 3.1.1 energy consumption amount assessment: EPI score 70.1 (architecture sector 29.9/ mechanical sector 25.8/ electronic sector 15.4)
- 3.2.1 alternative energy use: Thermal heat pump system takes up 5% of the heating/cooling load, BIPV system installed.

8) Ministry of Public Administration and Security · Ministry of Knowledge Economy presentation data, 2009

9) Korea Institute of Construction Technology analyzed the building energy efficiency grade, and assigned the grades per area energy use quantity, 1 grade below 300, 2 grade 300-350, 4 grade 400-450, 5 grade 450-500.

 

- 3.2.2 lighting energy saving : satisfying the average illuminance level on the work plane in the typical floor office space, ceiling plane average lighting density below 13W/㎡ ; average lighting density 11.42 W/㎡.

*Table 4. Overview of Gyeonggi S City Hall construction*

| Division | Contents | Remarks |
|---|---|---|
| Location | Gyeonggi-do | |
| Structure | Steel frame - reinforced concrete, steel frame | |
| Site area | 74,452.50㎡ | |
| Construcri on area | 12,294.76 | |
| Building coverage ratio | 16.52% | |
| Floor-area ratio | 66.91% | |
| Total floor space | 75,611.81 | |
| Landscapin g area | 29,505.81 (Court: 15% of the site area /39.63%) | |
| Number of parking | 1,108대 ( law : 551-work /11-Disabled ) | Area of parking lots (First,Second basement) 약 22,000㎡ |

*Table 5. Evaluation item score that is related to S City Hall carbon emissions*

| Category | Evaluation item | | Credits | Obtain score |
|---|---|---|---|---|
| Energy use | 3.1.1 | Energy performance | 15 | 6.06 |
| | 3.2.2 | Energy saving of lights | 6 | 4.2 |
| | 6.1.1 | Reducing $CO_2$ emission | 3 | 2.1 |
| | 9.2.1 | Auto temperature adjusting device for each room | 2 | 0 |
| Material resource | 4.2.2 | Use of eco-friendly certified products | 3 | 3 |
| Water | 5.2.2 | Rain water harvesting | 3 | 3 |
| | 5.2.3 | Grey water facility | 4 | 4 |
| Carbon offset | 3.2.1 | Use of new/renewable energy | 2 | 2 |
| | 8.1.2 | Ratio of ecological area | 7 | 7 |
| Total | | | 45 | 31.36 |

*Table 6.. Get Item point of energy sector in the S City Hall*

| Cate gory | Sub-category | Evaluation item | Cred its | Obtain score |
|---|---|---|---|---|
| 3. Ener gy | 3.1 Energy use | 3.1.1 Energy consumption | 15 | 6.06 |
| | 3.2 Energy saving | 3.2.1 Use of alternative energy | 2 | 2 |
| | | 3.2.2 Lighting energy saving | 6 | 4.2 |
| Subtotal | | | 23 | 12.26 |

### 4.3. S-city hall building life cycle carbon emissions evaluation result

#### 4.3.1. The life cycle carbon emissions evaluation summary and evaluation range

S-city hall building is a steel frame-RC structure with the site area 74,452.50㎡, with the basement 2 floors, above ground floor 9 floors(1) building. The carbon emissions evaluation was done with the total gross floor area 75,611.81㎡ as standard. The consumption units, to calculate the 'energy consumption index' and 'water resource carbon emission index,' utilized the S-city hall building real measurement data. For 'carbon cancelling index' calculation, general landscaping statistics data was used; for the renewable energy, real measured data as the standard. Each index's consumption unit source and the carbon unit source are in Table 7.(life cycle 40 years)

*Table 7. Carbon intensity and calculating consumption per unit of S city hall carbon emissions*

| category | Consumption per unit of original | Source of carbon intensity |
|---|---|---|
| Energy use | S city hall building management team measured data | Emissions calculation guidelines of each facility, District Cooling and Heating |
| Material resource | S city hall amount statements | LCI DB |
| waste | 2nd national waste statistics survey(Ministry of Environment) | Emissions calculation guidelines of each facility |
| water | S city hall building management team measured data | Carbon emissions per unit associated with the consumption of constant[10] Carbon intensity associated with sewage generation[11] |
| carbon offset | Carbon neutral city, S city hall building management team measured data | Korea Forest Research Institute, Emissions calculation guidelines of each facility |

#### 4.3.2. The carbon emissions from the energy consumption per operation stage use

The consumption unit calculation for the energy consumption index carbon emissions used the 2012 standard S-city hall building energy use amount measurement data. The carbon emissions analysis per operation stage use energy consumption is shown in Table 8.

- The biggest ratio in the carbon emissions is taken

10) Ha, K.W., Carbon Emission Characteristic and Mitigation mesures for Multi-regional Water Supply System, 2011

11) korea land & housing corporation, green city modelling and CDM business strategy, 2011

by the lighting-ventilation-the other sector, taking up 51% in the carbon exhaust amount per total operation stage energy consumption. The reason for the big carbon emissions is because the electricity is the major energy source.

- At present S-city hall building is using both the electricity and the district cooling and heating for the A/C energy source. The reason there are less carbon emissions compared to the lighting-ventilation-the other sector is because of the use of the district cooling and heating. The carbon emissions of the district cooling and heating is less than that of electricity.

We can see in Table 8 the lighting-ventilation-the other sector is producing the most carbon emissions. The energy was distributed equally in lighting, ventilation, office electronics use, but the energy use amount per each use wasn't known. Since 2010 green building approval standard revision, the energy sector 3.1.2 electric meter installation item was installed in the office green building approval for probably the same reason. In S-city hall building, Since it was approved in 2009, the electric meters were not installed in the building to measure the energy use per each use. Since the item was installed, though, evaluation scores are shown as average 0.9 out of 2 in total, which exemplifies that the system is not being well implemented.

*Table 8. S. City hall operation stage carbon emissions by energy source*

| category | Heating | Cooling | Hot water | Utility |
|---|---|---|---|---|
| Carbon Emissions ($tCO_2$) | 61,608.4 | 41,919.2 | 2,691.6 | 110,514.4 |
| Energy Source | Electricity· DCH | Electricity· DCH | DCH | Electricity |
| ratio(%) | 28.4 | 19.3 | 1.2 | 51.0 |

DCH = District Cooling and Heating

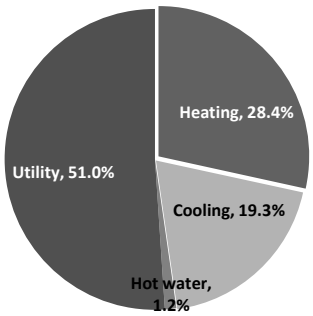


*Fig 8. S City Hall by usage energy consumption rate*

In order to reduce the energy use amount, it is required to implement the electric meters that show per use energy amount in comparison.

*Table 9. Results of evaluation of the life cycle carbon dioxide emissions of S City Hall*

| Division | | Emissions ($tCO_2$) | Carbon emissions per unit area ($tCO_2/m^2$) | Ratio (%) |
|---|---|---|---|---|
| Energy use | Heating | 61,608.4 | 2.87 | 71.81 |
| | Cooling | 41,919.2 | | |
| | Hot water | 2,691.6 | | |
| | Lighting, ventilation and other | 110,514.4 | | |
| | Sub-total | 216,733.6 | | |
| Material resource | Production of material | 58,144.73 | 0.77 | 19.24 |
| waste | Household waste | 1,632.28 | 0.63 | 1.58 |
| | Construction stage waste | 3,523.8 | | |
| | Demolition stage, waste | 1,596 | | |
| | Sub-total | 6,752.08 | | |
| water | Constant consumption | 518.8 | 0.02 | 0.52 |
| | Sewage generation | 932.9 | | |
| | Heavy water use | 112.1 | | |
| | Sub-total | 1339.6 | | |
| carbon offset | Timber | 387.2 | 0.27 | 6.85 |
| | Renewable - solar power | 1,304.8 | | |
| | Renewable - Geothermal heat pump | 19,010 | | |
| | Sub-total | 20,702 | | |
| total | | 262,268.01 | 4.02 | 100 |

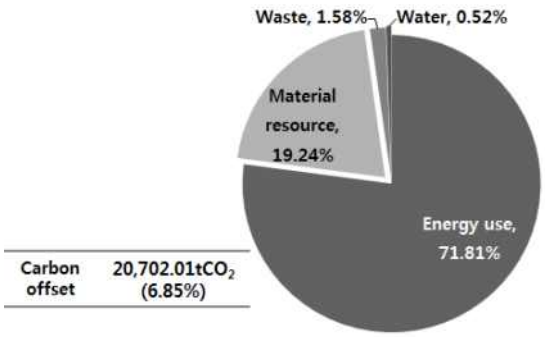


*Fig 9. Percentage of sectoral carbon emissions*

### 4.3.3. S-city hall building life cycle carbon emissions evaluation result

The carbon emissions life cycle evaluation results are as follows in the Table 9.

○ 'energy consumption (utility) : index' 2.87 $tCO_2$ / ㎡, total exhaust amount 216,733.6 $tCO_2$

○ 'life cycle carbon emission (material production):

 

index' 0.77 $tCO_2$ /㎡, total exhaust amount 58,144.73 $tCO_2$ .

○ 'solid waste carbon emission: index' 0.63 $tCO_2$ /㎡, total exhaust amount 6,752.08 $tCO_2$ . From this life solid waste 1,632.28 $tCO_2$, construction solid waste 3,523.8 $tCO_2$ , demolition solid waste 1,596 $tCO_2$ .

○ 'water resource carbon emission: index' 0.02 $tCO_2$ /㎡, total exhaust amount 1339.6 $tCO_2$. From this the constant consumption 518.8 $tCO_2$, sewage 932.9 $tCO_2$, heavy water utilization reduction amount 112.1 $tCO_2$.

○ 'carbon cancelling: index' 0.27 $tCO_2$ /㎡, total cancelling amount 20,702 $tCO_2$. From this trees cancelling 387.2 $tCO_2$ , renewable energy cancelling 20,314.83 $tCO_2$ .

○ for these evaluated office buildings life cycle $CO_2$ exhaust amount in total is 4.02 $tCO_2$ /㎡ (total 262,268.01 $tCO_2$). (only, the numbers can change later in the follow-up studies)

In Fig. 9 it appeared that the energy consumption sector 71.81%, material production sector 19.24%, solid waste sector 1.58%, water resource 0.52%, carbon cancelling sector 6.85%. The sector that takes up the most of the life cycle carbon emissions turns out to be the energy consumption sector.

### 4.4. conclusion

When the S-city hall buildings' carbon emission results are assessed with 40 year life span, the part with the most carbon emissions is at the operation stage energy consumption. Also, among the operation stage energy consumptions, per energy use amount carbon emission quotient was used to find that the electricity use produce the most carbon emission amount.

In case of the S-city hall building, most of the energy use amount is provided from the electricity. In order to reduce the carbon emissions, while the energy use amount reduction itself can be a way, another way to do it is to change the energy source to the lower carbon emission quotient.

## 5. result

### 5.1. result summary

In this study we reviewed the domestic green building approval system approval current condition, with the office buildings current approval condition in particular. Also, we categorized and analyzed the carbon emissions related evaluation items within the green building approval standard, from which we selected the S-city hall building as a representative case and assessed the carbon emissions per operation stage use energy consumption and the life cycle carbon emissions. The results are as follows:

1. There are 2,959 building evaluation approval cases in total from 2003 to August, 2012, through the green building approval system, with 1,884 pre-approval cases and 1,075 approved cases. Among them the office buildings are 16.51% (311 cases) in the pre-approval stage and 12.74% (137) cases in the approval stage.

2. We analyzed 136 approval cases per 2006 approval standard and 88 office building cases per 2010 approval standard, with the resulting average and standard deviation per sector evaluation scores, to find the approval scores' preponderance and propensity.

3. Among the green building approval standard items, the carbon emission related items are categorized. There exist the carbon emission related evaluation items, but no items for the carbon emissions' quantitative evaluation. Thus with the green building approval assessment scores alone, the quantitative carbon emission reduction amount cannot be predicted.

4. We selected the S-city hall building as a representative case. The S-city hall building is an office building that achieved 2nd best grade in the green building approval. However, the S-city hall buildings are evaluated as below the medal grade in the energy efficiency grade, with per unit 1st energy consumption amount 603.3kWh/㎡.

5. S-city hall building life cycle carbon emissions evaluation resulted in the energy consumption sector 71.81%, material production sector 19.24%, solid waste sector 1.58%, water resource 0.52%, carbon cancelling sector 6.85%. When the carbon emission results are assessed with 40 year life cycle, the part with the most carbon emissions is at the energy consumption sector.

### 5.2. The study limitations and the follow-up study plan

In this study we took one office building that received the green building approval as a case study. In the future we will analyze many office buildings per their approval scores in relation to the carbon emissions, to explore the quantitative characteristics of the office buildings in their

carbon emissions. Also, if there are studies in other types of the buildings as well, along with their life cycle carbon emissions, then we can get the per type carbon emission characteristics comparison in building planning, along with the energy and carbon emissions reduction strategy.

## Acknowledgement

"This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government(MEST)(No. 2005-0049719, 2011-0028794)."

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Received May 13, 2013;
Final revision received January 28, 2014;
Accepted February 13, 2014;

 