PROCESS OF COMMUNITY-BASED SUSTAINABLE CO_2 MANAGEMENT

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ABSTRACT: According to the United Nations Framework Convention on Climate Change (UNFCCC), many countries around the world have been concerned with reducing Greenhouse Gas (GHG) emissions. Reducing the level of building energy consumption is particularly important in bringing GHG down. Because of this, many countries including the US and the EU are enforcing energy-related policies. However, these policies are focused on management of single types of buildings such as public buildings and office buildings, instead of management on a national level. Thus, although various policies have been enforced in many countries, CO_2 management on a national level is still not an area of focus. Therefore, this study proposed a community-based CO_2 management process that allows government-led GHG management. The minimum unit of the community in this study is a plot, and the process consists of three steps. First, the current condition of the GHG emission was identified by plot. Second, based on the identified results, the GHG emission reduction target was distributed per plot by reflecting the weighted value according to (i) the target CO_2 reduction in the buildings in the standard year, (ii) region, and (iii) building usage and size. Finally, to achieve the allocated target reduction, building energy management was executed according to the properties of the building located on each plot. It can be expected that the proposed community-based CO_2 management process will enable government-level GHG management, through which environment-friendly building construction can be promoted.

Keywords: Carbon Dioxide; Carbon Dioxide Management; Carbon Dioxide Reduction; Community

1. INTRODUCTION

Recent global efforts to reduce greenhouse gases (GHG) are primarily attributed to the United Nations Framework Convention on Climate Change (UNFCCC). As of 2010, 30 countries have been designated as GHG reduction target countries. As the second phase of compulsory reduction countries will be determined in 2013, more efforts to reduce GHG are expected. One method used in such efforts is the reduction of building energy consumption.

According to the International Energy Agency (IEA), the amount of CO_2 emissions due to the energy consumed by buildings is as much as a quarter of the total CO_2 emissions [10]. Accordingly, advanced countries such as the USA and the UK are attempting to reduce their CO_2 emissions by introducing policies related to green construction. Such attempts are particularly focused on public buildings and large shopping malls that use much more energy than smaller buildings [6].

Recent studies have focused less on attempts of single building units to reduce GHG and more on attempts to reduce community-based GHG either in newly created cities or in existing cities [3, 8]. Community-based GHG management, however, often stops simply at a one-time attempt to create a zero-energy city. This minimizes GHG emissions through environment-friendly designs that utilize various passive elements and highly efficient equipment in buildings constructed in communities. Also, CO_2 management through the city-based approach considered in existing cities is an overall management method for entire cities, including their infrastructure, rather than controlling each building located in the city. This means the GHG generated by buildings cannot be controlled. In other words, despite the introduction of numerous policies, a clear standard on how much GHG reduction should be achieved in each building has yet to be proposed.

This study proposed a process and methodology that helps promote sustainable community-based GHG management. The proposed process, which is based on plots, distributes the national-level GHG reduction to buildings by plot according to (i) the target CO_2 reduction in the buildings in the standard year, (ii) region and (iii) building usage and size, so that the distributed target CO_2 reduction is achieved by the properties of each building.

2. PREVIOUS STUDIES

2.1 CO_2 Management Using City-based Approach

Recent GHG reduction efforts have focused more on the city-based approach than on building-based reduction by reducing the energy consumption of buildings. Data announced by the World Bank in 2009 determined the overall city-based GHG emission elements and showed the overall GHG reduction by reducing the GHG reduction of specific elements that are problematic. In that report, the World Bank presented a city-based approach to reduce GHG emission by promoting the methodology in six cities in six countries—Curitiba in Brazil, Stockholm in Sweden, Singapore, Yokohama in Japan, Brisbane in Australia, and Auckland in New Zealand [8].

Aside from the cities and countries that were mentioned in the World Bank report, the UK has made it compulsory for all houses built from 2016 to be Carbon-Zero Houses [4]. In Europe, under the leadership of the EU, the Energy Performance Building Directive (EPBD) policy has already been in progress since the early 2000s. In fact, the UK's EPBD policy, along with Energy Performance Certificates (EPCs), was introduced as part of the country's efforts to promote the EPBD, which the EU has recommended [4, 6].

As such, there have been various city-based GHG reduction attempts, but these systems and methodologies do not concern each building located in the corresponding community. Rather, they are whole-city GHG management systems that include the various infrastructures located in the city.

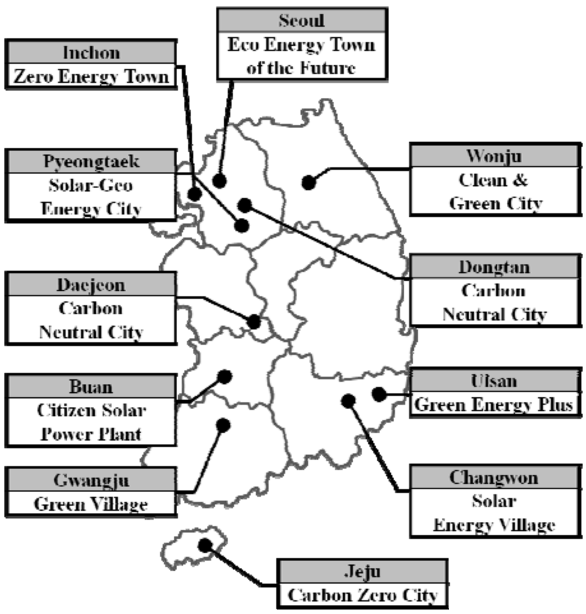

Figure 1. Zero Energy Cities in Korea

2.2 Status of CO_2 Management in South Korea

South Korea, which is the target of this study, has recognized the importance of GHG management, which is why the country focuses on GHG monitoring research. According to the study conducted by the Seoul Development Institute (SDI) in 2009, the country's total CO_2 emission has been determined by CO_2 emission by field, including the industry, transportation, household, commercial, and public sectors. This study also mentions the importance of determining the CO_2 emission by individual industry and by land use. Particularly in determining the CO_2 emission by land use, this report suggests a monitoring method by building per plot, which this study aims to promote [3]. SDI's study focused only on simple GHG emissions and did not consider overall community-based monitoring of GHG emissions.

As opposed to the lack of studies on existing communities, there have been various policies or studies on new communities. New cities that are currently being built comply with the Zero-Energy City policy. Fig. 1 shows the current status of the construction of new cities [2]. As shown in Figure 1, a total of 11 new communities are being constructed in Korea, including the Eco Energy Town of the Future in Seoul, based on the Zero-Energy City policy as of 2010. Newly built communities based on the Zero-Energy City policy implement compulsory use of passive elements, such as super-insulation, exterior insulation, and heat recovery ventilation, along with the use of renewable energy, such as highly efficient equipment like LED lighting and geothermal, biomass, and solar energy.

3. PROCESS OF COMMUNITY-BASED SUSTAINABLE CO_2 MANAGEMENT

3.1 Basic Concept and Process

The basic concept of community-based sustainable CO_2 management is as follows. First, the minimum unit managed is the plot. GHG management by plot allows management by block, dong, gu, city, province, and country. The complete process of community-based sustainable carbon dioxide management using such a basic concept is shown in Fig. 2.

3.2 Step 1: CO_2 Emission Survey

Focusing on the CO_2 emission survey, step 1 consists generally of the following three tasks. First, the study collects the yearly electricity and gas usage data by plot. The collected energy usage is converted into CO_2 emission using the coefficient of emission by energy type, and the resulting CO_2 emission is used to create a CO_2 map by plot.

3.2.1 Step 1-1: Collecting yearly electricity and gas usage data in the standard year

The first task is to collect the yearly energy usage data by plot. The plots are only those on which buildings are located; sites of new building construction are excluded.
The CO_2 emission during the construction phase is extremely smaller than, and should be separated from, that generated in the operating and maintenance phases [7.9]. Management of such CO_2 emission is performed in Step 3-3. The energy usage data required at this point are the yearly electricity and gas usage data (January to December). This is to allow use of the energy consumption under the same conditions as the climate condition or the holidays in Step 2, wherein the target GHG reduction is distributed by plot. This process will not cause much difficulty if the plot from which the data collection is conducted has single buildings. If the plot has commercial-residential complexes and multi-family housing buildings such as apartments, however, buildings are often registered with the representative plot, which may cause either excessive estimation or omission [3]. To solve this problem, the study collected the energy usage data by building if more than one building was located on one plot.

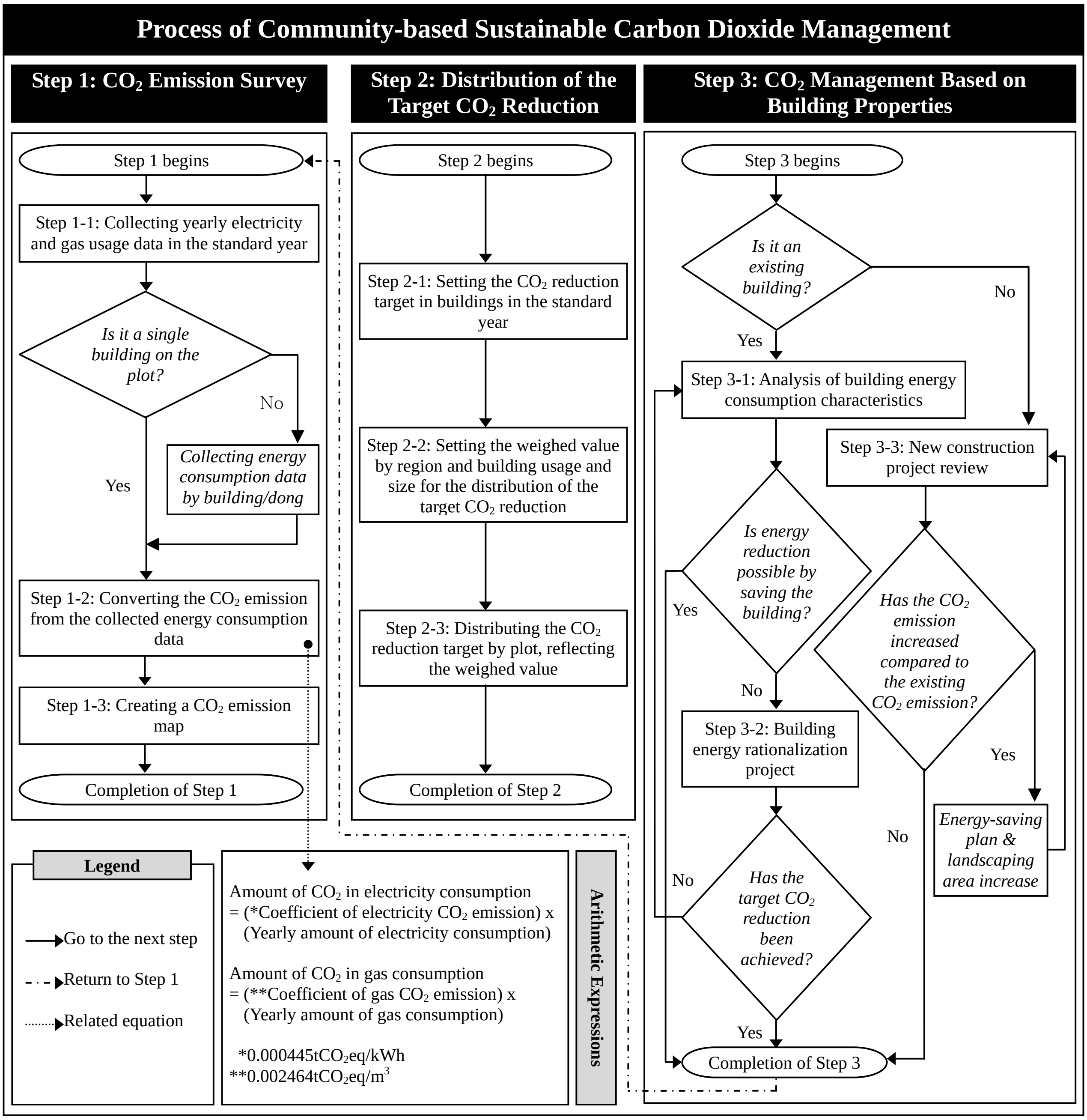

Figure 2. Process of Community-based Sustainable Carbon Dioxide Management

3.2.2 Step 1-2: Converting CO_2 emission from the collected energy consumption data

The collected yearly energy usage is converted into the CO_2 emission using the coefficient of gas and electricity emission by energy type, as shown in equations (1) and (2) [1].

The amount of CO_2 in electricity consumption
= (Coefficient of electricity CO_2 emission) x
= (Yearly amount of electricity consumption) (1)
where, the coefficient of electricity CO_2 emission is $0.000445tCO_2eq/kWh$ [1].

The amount of CO_2 in gas consumption
= (Coefficient of gas CO_2 emission) x
= (Yearly amount of gas consumption) (2)
where, the coefficient of gas CO_2 emission is $0.002464tCO_2eq/m^3$ [1].

The sum of the CO_2 emissions that were calculated by converting the electricity and gas usage is the CO_2 emission in the corresponding plot in the standard year. Using this CO_2 emission, the next task is to create a CO_2 map, and the target CO_2 reduction distributed to each plot in Step 2 is achieved in Step 3.

3.2.3 Step 1-3: Creating a CO_2 emission map

Using CO_2 emission by plot produced in step 1-2, a

CO_2 map is created based on the existing land registration map. By marking the CO_2 emission data resulting from the energy usage data collected in the standard year on the land registration map, sustainable management of CO_2 emissions is possible. Fig. 3 shows an example of the CO_2 map created in the aforementioned process.

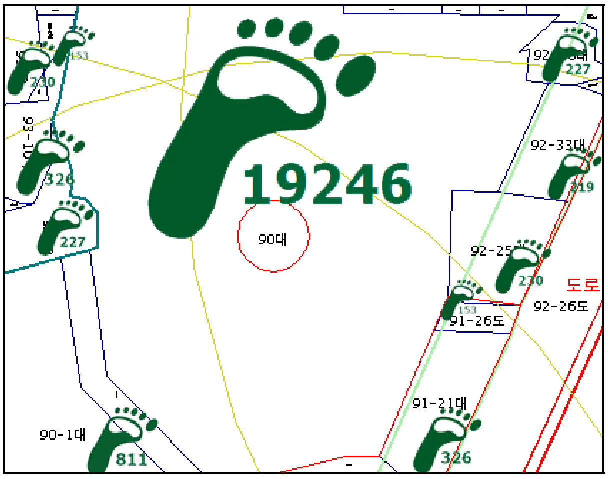

Figure 3. Example of CO_2 map

The created CO_2 map is not meant only to show the CO_2 emission by plot, but also to control the regions with higher CO_2 emissions if CO_2 emission management is conducted not only by plot but also by block, dong, or any other upper-level stage. Additionally, it shows the CO_2 emissions as one of real estate indexes, by marking the CO_2 emission along with the existing real estate indexes, such as legal usage, floor space index, building-to-land ratio and land value by public announcement, with the certified copy of the real estate register or the land register by plot.

3.3 Step 2: Distribution of the Target CO_2 Reduction

Step 2 is the phase in which the target CO_2 emission by plot is distributed to reduce the CO_2 emission. Toward this end, the study first set the target CO_2 reduction with the building energy saving in the corresponding year. It is not reasonable to distribute the target CO_2 reduction simply by area or population. Thus, the weighed value according to region and building usage and size is first set, and the target CO_2 reduction is distributed by plot by reflecting the set weighed value.

3.3.1 Step 2-1: Setting the target CO_2 reduction in buildings in the standard year

To distribute the target CO_2 reduction by plot, it is first necessary to set how much CO_2 reduction must be achieved in buildings in the given year. The government should set a national CO_2 reduction target, according to the amount of CO_2 reduction to be achieved in buildings. Since both the national target CO_2 reduction and the target CO_2 reduction in buildings can change if the summer or winter seasons in the given year are expected to be either hotter or colder than those in the previous years; or if the country is planning to hold international events such as the Group of Twenty (G20), the Asia-Europe Meeting (ASEM), the World Cup, or the Olympics, the target reduction can be partly adjusted. The decision on the adjustment of the CO_2 reduction target, however, is completely made by the government.

Table 1. Electricity usage in August 2010 classified by gu of Seoul

Gu	Electricity usage (kWh)	Area (km^2)	kWh/km^2
Jongno	175,492,727	23.91	7,339,720.91
Jung	277,075,668	9.96	***27,818,842.17***
Yongsan	144,692,061	21.87	6,616,006.45
Seongdong	174,794,026	16.85	10,373,532.70
Dongdaemun	150,203,372	14.20	10,577,702.25
Seongbuk	142,044,411	24.57	5,781,213.31
Dobong	106,952,764	20.70	5,166,800.19
Eunpyeong	123,269,701	29.69	4,151,892.93
Seodaemun	122,722,489	17.60	6,972,868.69
Mapo	180,464,329	23.87	7,560,298.66
Gangseo	194,199,164	41.43	4,687,404.39
Guro	196,055,959	20.14	9,734,655.36
Yeongdeungpo	274,474,700	24.57	11,171,131.46
Dongjak	124,732,234	16.35	7,628,882.81
Gwanak	166,417,511	29.57	5,627,917.18
Gangnam	***496,809,113***	39.54	12,564,722.13
Gangdong	149,326,404	24.58	6,075,118.14
Songpa	253,764,128	33.88	7,490,086.42
Jungnang	106,419,136	18.50	5,752,385.73
Nowon	155,618,185	35.43	4,392,271.66
Seocho	344,558,576	47.00	7,331,033.53
Yangcheon	153,791,656	17.40	8,838,600.92
Gwangjin	181,960,313	17.05	10,672,159.12
Gangbuk	91,080,908	23.61	3,857,725.88
Geumcheon	159,193,014	13.01	12,236,204.00

3.3.2 Step 2-2: Setting the weighed value by region and building usage and size for the distribution of the CO_2 reduction target

The CO_2 reduction target in buildings in a given year, should be distributed by plot. It is unreasonable, however, to distribute it simply by area or population. Since the types or sizes of buildings differ by region, which determines the CO_2 emission in a region, distribution of the CO_2 reduction target should consider the weighed value by region and building usage and size. Table 1 shows the electricity usage by gu in Seoul in August 2010, which is the time when electricity usage was highest due to the higher cooling demand. It shows that even in Seoul, the CO_2 emission by area differs drastically. The usage in Gangnam-gu was highest, whereas the electricity usage by area was highest in Jung-gu. This signifies that it is necessary to apply the weighed value by region to the distribution of the CO_2 reduction target.

The weighed value by building usage and size must also be considered, along with the weighed value by region. The “Building Act” and the “National Land Planning and Utilization Act,” the two legislations related to buildings in South Korea, define the size of buildings that can be constructed according to the designated legal usage by plot.

Table 2. Area classification under the laws of Korea

Classification Level 1	Classification Level 2	Classification Level 3
Urban area	Residential Area	Class-I exclusive residential area
		Class-II exclusive residential area
		Class-I general residential area
		Class-II general residential area
		Class-III general residential area
		quasi residential area
	Commercial Area	Central commercial area
		General commercial area
		Neighboring commercial area
		Circulative commercial area
	Industrial Area	Exclusive industrial area
		General industrial area
		Quasi industrial area
	Green Area	Conserved green area
		Production green area
		Natural green area
Control area	Conservation management area	N/A
	Production management area	N/A
	Planning management area	N/A
Agricultural and forestry area	N/A	N/A
Natural environment conservation area	N/A	N/A

Table 2 shows the land usage stipulated in the current building laws in South Korea [2]. The legal use of land under the law is categorized into the following three stages. The first stage categorizes the land usage into Urban Areas, Control Areas, Agricultural and Forestry Areas, and Natural Environment Conservation Areas. Except for the Agricultural and Forestry Areas and the Natural Environment Conservation Areas, the other two areas are subcategorized further. Particularly, Urban Areas are divided into four subcategories: Residential Areas, Commercial Areas, Industrial Areas, and Green Areas; and each subcategory is further divided based on its detailed use. Therefore, such categorization levels should be considered when setting the weighed value by usage. Also, the criteria by usage differ by size, and therefore, the weighed value by size should also be considered when setting the weighed value by usage.

The weighed value resulting from this step is set by considering the CO_2 emission ratio by region, population, or population density using the CO_2 emission condition surveyed in Step 1. A detailed study related to this step shall be conducted in the future.

3.3.3 Step 2-3: Distributing the CO_2 reduction target by plot, reflecting the weighed value

As such, the CO_2 reduction target by plot should consider the weighed value resulting from Step 2-2 since each plot differs from the other plots by the region where it is located, the legal usage defined, and the size. This method allows a request for CO_2 reduction per plot that is more reasonable than what results from the existing method, which simply reduces the arbitrary ratio of the reduction against the previous one.

3.4 Step 3: CO_2 Management Based on Building Characteristics

Step 2 dwelt on the distribution of the CO_2 reduction target by plot in the given year. Step 3 shows how to satisfy the distributed CO_2 reduction target, which is related to reducing building energy consumption for GHG reduction. First, the process changes depending on whether the target building located in each plot is an existing one or a newly built one. If it is an existing building, it should be further determined if the reduction of energy consumption is to be made simply by saving building energy through the analysis of building energy consumption characteristics or by the building energy rationalization project. If the building is new, the process considers a new construction project so that the building can emit less CO_2 than the current CO_2 emitted in the corresponding plot.

3.4.1 Step 3-1: Analysis of building energy consumption characteristics

To reduce the energy consumption of an existing building, the building’s energy consumption characteristics should first be analyzed. Accurate analysis of energy consumption characteristics can be conducted by modeling the target building using an energy simulation program such as EnergyPlus or e-Quest offered by the Department of Energy in the USA, and simulating the virtual data in the region where the building is located. While such a method allows accurate analysis of the building's energy consumption characteristics, the modeling may take too much time. One method that can solve this problem is to have a specialist survey the building. In Germany, a building energy rationalization project often requires dispatching a specialist to save time in analyzing the building energy consumption characteristics. While saving time, this method can make the analysis results dependent on the individual specialist's subjective viewpoint. Thus, further research is required by considering all these points so as to propose an optimized analysis of building energy consumption characteristics.

3.4.2 Step 3-2: Building energy rationalization project

After the energy consumption characteristics analysis of the target building located in each plot, the results should determine if a building energy rationalization project is needed. This is because depending on the energy consumption characteristics of the building, energy consumption reduction can be sufficiently made simply by saving energy that is used in the building. If that approach is no longer effective, the building energy rationalization project can begin. In conducting the building energy rationalization project, studies such as that of Park and Hong [5] should be referred to.

3.4.3 Step 3-3: New construction project review

As opposed to Steps 3-1 and 3-2, Step 3-3 is related to new buildings. For existing buildings, energy is saved either by simply saving energy that is consumed in the building or by the overall improvement of the building's energy consumption through a building energy rationalization project.

In the case of new buildings, however, a separate management plan should be established since the target buildings have yet to be built. New buildings can be divided into buildings that are currently being planned for construction and those that are currently in construction. In the case of the former, the CO_2 reduction target should be achieved by reviewing the construction plan. In the USA, the Leadership in Energy & Environment Design (LEED) is already in use, so that while planning a new building, the construction plan is reviewed by an energy simulation program such as EnergyPlus or e-Quest. In fact, before the American Institute of Architects (AIA) cites 10 constructions plans as environment-friendly designs each year, they review the plans using the aforementioned energy simulation [11]. As such, review of the construction plan converts the CO_2 emission from the electricity and gas usage in a new building and compares the result with the existing CO_2 emission. If the CO_2 emission of the new plan is lower than the existing CO_2 emission, the plan passes the test. If not, the plan is revised, for example by cancelling out the CO_2 emission through the increase in the landscaping area, so as to make the CO_2 emission lower than the existing emission. If this review process results in a considerable reduction of the CO_2 emission, the government can grant the plan incentives for the floor space index, building-to-land ratio, and the mitigation in height limit so as to promote environment-friendly construction. However, such a review of new construction plans requires the support of the government and revisions of related laws.

In the case of the latter, CO_2 emissions management is focused on minimizing CO_2 emissions in the construction stage. There are few researches, however, on how to determine the CO_2 emission in the construction stage and its management method, so additional studies are required.

4. CONCLUSIONS

This study proposed a community-based sustainable CO_2 management process that allows national GHG management through building GHG management by plot. Before such process was proposed, a process that is similar to the proposed process was reviewed to verify that no existing process made the same attempt that this study made, through which the validity of the proposed process was established.

The proposed process in this study generally consisted of three steps. In Step 1, the first phase in conducting the CO_2 management by plot, a survey was conducted on the current condition of the building GHG emission by plot. Based on the survey results in Step 1, the target GHG reduction to be distributed to the buildings is determined in Step 2, and the total GHG reduction is distributed by plot by reflecting the weighed value by region and building usage and size. Finally, in Step 3, the building energy management is performed by plot to meet the distributed target GHG reduction. At this time, if the new building plan shows a more significant reduction in the CO_2 emission than the current condition, the plan is granted various incentives such as the floor space index, building-to-land ratio, and the mitigation in height limit.

It is believed that the proposed process will solve the problem that existing domestic and foreign building energy-saving policies often show as a limitation. They do not provide guidelines on how much energy should be saved in each building [6]. This study also showed that environment-friendly construction design can be promoted by granting various incentives if the new construction design results in lower CO_2 emissions than that in the given plot.

The proposed process is still in its initial stage, however, and needs to be complemented by additional research. The proposed process also needs to be verified by conducting a case study.

ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2010-00027246).

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