A STUDY ON EVALUATION METHODS FOR THE ENVIRONMENTAL LOAD REDUCTION EFFECTS ACHIEVED VIA SUSTAINABLE BUILDING TECHNOLOGIES

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Abstract - A method to evaluate the environmental load reduction effects of energy saving when applying sustainable building technologies is presented. We analyze the methods proposed in existing environmental impact assessment guidelines of sustainable building technologies and suggest differentiated data collection scopes and system boundaries. Sustainable building technologies are categorized into new and renewable energy technology, high-performance Envelope technology, and high-efficiency equipment technology, and we propose evaluation methods for each.

Keywords - Sustainable building technology, Environmental load evaluation method, Life cycle assessment

I. INTRODUCTION

Since the industrial revolution, the resulting rapid economic growth and the massive use of fossil fuels have caused serious environmental problems, such as global warming. Rising concerns about such problems haverecently induced strengthened international climate agreements and national policies encouraging the use of the sustainable building materials. Although various sustainable building technologies have been proposed in line with this trend, methodologies for the reliable evaluation of the environmental load reduction effects of these technologies are hardly available. Therefore, in this study,we propose a new evaluation method for assessing the environmental load reduction effects achieved via the decreased energy consumption of buildingsafter the application of sustainable building technologies. The proposed method can be applied for a detailed evaluation of the representative architectural technology groups.

II. EXISTING METHODS FOR ENVIRONMENTAL LOAD EVALUATION

One of the most widely used methods for environmental load evaluation is life cycle assessment (LCA), which enables the overall evaluation of products for their entire life cycle, i.e., ‘from the cradle to the grave’. Based on the principles and procedures of the LCA method, environmental load evaluation requires significant effort and time for data acquisition. Consequently, several guidelines have been developed to simplify the systematic boundaries and data acquisition range by using evaluation targets and purposes, such as PAS2050 and the BRE-Material profile.According to the Korean Carbon Footprint Guidelines, building materials such as thermal insulations and windows are classified as manufactured products, and the boundaries of the evaluation system are restricted from the raw material collection stage to the production stage. On the other hand, the operating stage is included in the evaluation system for energy use products. Thus, an objective comparison and evaluation of environmental load reduction is impossible using the existing evaluation methods because the range of data collection varies for each architectural technology group.

III. SUGGESTIONS OF NEW METHODS FORTHE EVALUATION OF ENVIRONMENTAL LOAD REDUCTION EFFECTS

3.1. Functional Unit

Because LCA is generally performed on final products or services with major functions, the establishment of functional units is very important. In addition, it should be emphasized that the function of the product system defines its purpose and that a functional unit serves as a measure of the performance of the intended function. Functional units are established based on the unit product sold in the market. A separate functional unit can be established if the market unit is unclear.

Table 1 shows the categorized functional units generally used in LCA. Because the primary purpose of this study is to indicate the environmental load reduction effects achieved via energy saving, the functional units of energy, W and kWh, are used.

Establishing the functional unit and displaying the environmental load in basic units allows us to objectively compare and assess the environmental loadof various products manufactured via sustainable low-energy-consumption technologies.

Table 1. Functional Units Categorized by Life Cycle

Category	Functional Unit
Material	Production of 1 kg or 1 ton of raw materials/parts
Energy	Production of 1 MJ or 1 kcal of energy (generation of 1 kWh of electricity)
Transfer	Transfer of 1 ton·km by each transportation method
Discard	Discarding 1 kg or 1 ton of material by each discarding method

3.2. Determination of the Evaluation Range

In order to reliably measure the environmental load caused by a product using the LCA method, it is necessary to clearly define its life cycle phases andthe system boundaries, which determine the data collection range for each phase. The life cycle stages consist of a series of procedures, such as the raw material mining, processing, manufacturing, operating, maintenance, discard, and recycling stages. The system boundaries are determined by the unit processes in the life cycle, and their scope depend on the use, assumptions made during the data collection process, and the purposes of the application of the research results. Fig. 1 shows the system boundaries of durable products suggested by the Korean Carbon Footprint Guidelines. According to the guidelines, the use scenario in the operating stage needs to be taken into account for renewable and high-efficiency energy facilities, as in the energy use products group. In addition, the building materials used, such as high-thermal-insulation sheaths, are classified as production materials and their system boundary for the evaluation only includes the manufacturing stage.

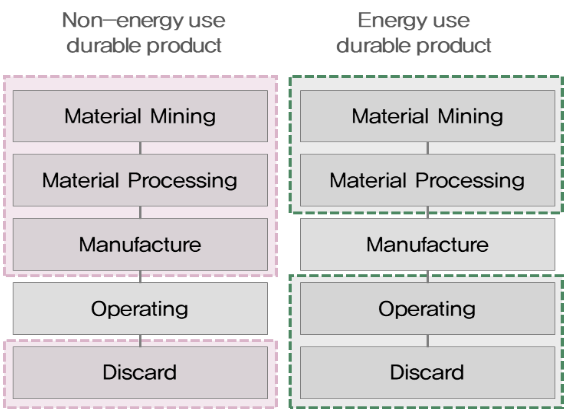

Fig 1. System boundaries of non-energy use (left) and energy use (right) durable products suggested by the Korean Carbon Footprint Guidelines.

Thus, it is impossible to perform an objective comparison and evaluation of the environmental load effects of sustainable construction technologies with the existing method because of inconsistencies in the data collection range and life cycles.

The primary objective of this study is to determine the energy saving and environmental load reduction effects achieved via application of sustainable construction technologies. Therefore, the data collection and evaluation processes are restricted to the use stage of the building materials. Furthermore, the environmental load caused during the manufacture and building stages were excluded from the analysis.

3.3. Result Presentation

There are various types of environmental loads in the LCA method, such as ozone layer destruction, human toxicity, water pollution, and global warming. The environmental load factor that has recently gathered the most attention is global warming, which is related to the Climate Change Convention. Taking into account the importance of evaluating the effects of greenhouse gases, this study suggests that: 1) the evaluation results should be limited to the categories related to the global warming impact, 2) the global warming index should be indicated in consideration of user convenience, and 3) the unit to be used is the carbon dioxide equivalent (CO_2eq).

IV. EVALUATION METHOD BY TECHNOLOGY GROUP

4.1. Evaluation of the Environmental Renewable Energy Technology

Renewable energy technologies use inexhaustibleenergy sources to produce electric or heat energy and include the wind, solar power, and geothermal technologies.

Because the amount of energy produced by renewable energy sources is equal to the energy consumption reduced in buildings, the annual environmental load reduction can be calculated via Equation (1) using the annual electricity production(kWh) and the CO2 emission ratio (kgCO2eq / kWh).

$$\underset{(kgCO_2/kW{\cdot}yr)}{\textit{Annual GHG reduction}} = \underset{(kWh/kW{\cdot}year)}{\textit{Annual Energy production}} \times \underset{(kgCO_{2eq}/kWh)}{CO_2 \textit{ emission factor}} \quad (1)$$

4.2. Evaluation of High-Performance Envelope Technology

High-performance Envelope technology reduces environmental loads by decreasing energy consumption via high-insulation windows and insulation reinforcements. In the evaluation process of high-performance Envelope technology, therepresentative products and standard performances for each applicable technology are selected. The rate of energy saved and the level of greenhouse gas reduction can be estimated by comparing the energy simulation results for cases in which sustainable technology is applied or not. Table 2 describes the conditions for the energy simulation to be considered in the evaluation of high-performance Envelope technology.

Table2: AnalysisConditions for the Evaluation of High-Performance Envelope Technology

Environmental Condition	Product quality	Building Condition	Load analysis data
• Exterior &Interior Conditions •Wind Direction& Velocity •Solar Insulation •Effective Penetration Temperature, •Effective Penetration Emissivity	•Solar Energy Transmittance & Reflectance •Visible Ray Transmittance •Infrared Transmittance & Reflectance •Heat Transmission Coefficient •Solar Heat Gain Coefficient	•Azimuth •Area •Volume •Window Area Ratio •Meteorological Data	•Cooling/Heating Temperature •Occupants •Infiltration •Internal Heat Schedule

In order to apply the proposed evaluation method, standardized building models are required to perform an analysis based on equal conditions. Although there are standard models for apartment houses in Korea, Korean models for general housing, commercial, and public buildings are not available. Therefore, further studies on the standard building models will be necessary prior to the evaluation of other types of buildings.

4.3. Evaluation of High-Efficiency Equipment Technology

High-efficiency equipment technology contributes to the reduction of the energy consumption of buildings by increasing the energy efficiency of heating and cooling systems, lighting, and air conditioning equipment. Similar to the evaluation process for high-performance Envelope technology, the evaluation process for high-efficiency equipment technology includes a selection of representative products, the determination of their standard performance, and a comparison of the energy simulation results. However, it also requires use scenarios.

The Korean Carbon Footprint Guidelines evaluate energy-consuming products with flexible use scenarios depending on the purpose of each product. These guidelines provide three use scenarios for this type of equipment: gas heat pumps, commercial electric heat pumps, and fan coil units.

The product scenarios presented in the guidelines can be used for certain evaluations, such as product life cycle, annual cooling/heating times, and cooling/heating load ratios.

CONCLUSIONS

This study examined evaluation methods of the environmental load reduction effectsresulting from energy savings achieved by the application of sustainable building technologies. Our main conclusions are as follows.

1. A commonly applicable evaluation method is proposed for assessing the environmental load reduction effects achieved via sustainable building technologies. In addition, this study also suggests a method for the detailed evaluation of three representative architectural technology groups.
2. Functional units were defined as W and kWh, based on the purpose of the evaluation, and the evaluation range of the building life cycle was limited to the operating stage.
3. The amount of energy savings during the operating stage of sustainable building technologies was estimated and combined with the CO_2 emission factor to evaluate the greenhouse gas reduction effects.
4. For the renewable energy technologies considered, their energy production was assumed to be equal to the resulting energy reduction, and the greenhouse gas reduction effect was evaluated with the energy production and the CO_2 emission factor.
5. In the environmental impact evaluation of high-performance Envelope technologies and high-efficiency equipment technologies, energy simulations can be used to calculate their reduced energy consumption after the application of sustainable building technologies.
6.
7. When an evaluation of the environmental load reduction of high-efficiency equipment technologies is performed, the life cycle, the annual cooling/heating times, and the cooling/heating load ratios of products in the use scenarios suggested by the Korean Carbon Footprint Guidelines can be used.

Because evaluation methods for the objective comparison and evaluation of environmental load reduction effects are unavailable, this study is significant as it proposes a detailed evaluation method for the environmental load reduction effects which is applicable to representative building technology groups.Although use scenarios for standardized buildings and equipment are required to apply the proposed evaluation method, Korean standard building models and use scenarios for evaluation of energy saving rates have not been established. Therefore, further studies will be performed on their quantifiable objectification by establishing standard buildings and use scenarios.

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