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Life-cycle Environmental Impact Assessment of High-rise Apartments

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Abstract

Concern about global environment has been increasing in recent years. Efforts to minimize the environmental impact to the globe as well as human beings have increased, especially in the late twentieth century. The study researches one of the solutions for the environmentally friendly building construction, which can contribute to sustaining the world environment. Assessment and proposals are made for high-rise apartments, one of the most popular construction types nowadays in Korea. Since the volume of high-rise apartment construction is so great, a small improvement in each building will make a great contribution. Assessments are made over the life-span of apartment buildings. A tool named EIAHA (Environmental Impact Assessment for High-rise Apartment) has been made through references from western examples, mainly in the UK. The components of EIAHA include passive design strategies, building materials, energy consumption during building operation and management/ maintenance. Although the issues are on a global scale, solutions are sought on regional scale. Korean high-rise apartments are assessed with the tool and suggestions for sustainable development are made mainly for improvement of embodied energy of building materials and the life of buildings.

Keywords: Environmental Impact assessment, Life-cycle, High-rise Apartments, EIAHA

1. INTRODUCTION

World societies have industrialized faster and faster in the last century, causing the globe to change much more quickly than ever before, thus provoking and aggravating problems. The patterns of human development associated with changes in land use, for example, have increased suburban development, industrial developments, and mineral extraction. The resultant pollutions of air, water and soil have caused the global ecological crisis. The survival of the human race depends upon us learning to live sustainably, which means living in harmony with the natural world and not in opposition to it.

The construction industry, along with the production of materials and their transportation, is mainly responsible for natural resources and energy consumption, and for producing wastes and pollutants. The development of the construction industry, especially in the second half of the twentieth century, has been characterized by a massive increase in the consumption of raw materials, an inexorable movement towards the use of more processed and energy-intensive materials and a widening extension of the external resource base appropriated by any given building project. A responsibility of the construction industry against environmental disorder is now greater than any other industry. About half of the energy consumption, which is a vital cause of resource depletion and environmental pollution, is related to buildings for both building operation and embodied energy, and consequently buildings produce almost half of CO_2, which is a primary cause of global warming.

This paper investigates current apartment building construction in terms of environmental impact in order to find sustainable development. Recently, about 500,000 apartment units are built in each year in Korea, with half of them in capital region alone. Continuous increase of housing construction for a further few decades will be an unavoidable phenomenon, unless the government wants to control the target of housing spread rate in the near future. Along with the increase in quantity, various types of apartments for a vast range of residents are required in future development. Among those issues, environmental concerns about construction and the life of a building need to be dealt with, as residents are eager to have a pollution-free environment. International environmental concerns will also affect future housing development. The success of future housing development will strongly depend on the concern of environmental impact during the building's life-cycle. The items of sustainable development in high-rise apartments are categorized in this paper, to develop a tool for assessing the sustainability of high-rise apartments. Current apartment buildings will be assessed with the tool named EIAHA (Environmental Impact Assessment of High-rise Apartments), followed by suggestions for sustainable apartment development.

2. ENVIRONMENTAL ISSUES AND BUILDINGS

(1) Issues of Sustainable Development

Rapid climatic change has proved to be the result of the accumulation of greenhouse gases such as carbon dioxide and nitrogen oxide. The phenomenon will raise sea level, which threatens some countries adjacent to the sea. The depletion of the ozone layer in the stratosphere by CFCs, man-made gases, crucially affects skin disease. Acid rain, water pollution, including rivers and oceans, and waste problems are also critical issues for the regional and global environment. Tropical forests are now being destroyed at an extraordinary rate, which is crucial to climate change and loss of biological diversity. Oil and

mineral resources are being consumed rapidly by industrialized and recently developing states, irreversibly depleting global reserves at a cost to underdeveloped countries and future generations. Moreover, the dumping of waste products into the air, sea and land has reached such a level that pollution has become a severe international and global problem.

To avoid a crisis developing from the above problems, there have been many efforts on an international level. The sustainable development theory comes in this context. Among many definitions, the definition of sustainable development adopted by the Brudtland Commission(1987) is the most widely used, defining it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This concept means looking ahead to the opportunities and constraints that will face us tomorrow, not merely those that face us today, and minimizing the use of resources and thereby the consequent increase in global entropy. Paul M. Smith and Kiki Warr (1991) emphasized four implications of the definition of sustainable development:

1. a concern about the relationship between resource use, population growth and technological development and advancement;
2. a concern about the production and the distribution of resources of food, energy and industry amongst the developed, developing and underdeveloped nations of the world;
3. a concern about uneven development, about the gross imbalance and ideological differences;
4. a concern about environmental degradation and ecological disaster

Recently, DETR(UK Department of the Environment, Transport and the Regions) explains the sustainable development into the four broad policy objectives(1999);

1 Social progress which recognizes the needs of everyone
2 Effective protection of the Environment.
3 Prudent use of natural resources.
4 Maintenance of high and stable levels of economic growth and employment

Sustainable development is, therefore, a new model of development, which aims to pursue the economic growth; high quality of life; and enhancement and maintenance of the environmental capital on which life depends. Although the idea of sustainable development concerns environmental degradation and ecological disaster, it is strongly human-centered. It is primarily concerned with maintaining human welfare through meeting human needs and ensuring the quality of human life. Sustainable development does not guarantee the needs or quality of life for animals or other living organisms, except where this will benefit humans. But at least, concern for human beings can be the first step to maintaining the ecosystem.

Sustainable development involves seemingly sound, common-sense adjustments to the way we do things. It does not mean a commitment to no real economic growth; rather it is a question of structural change of economic activities. It accommodates itself to the existing national and international economic systems. It aims to make the necessary modifications that will enable our everyday business activities to be sustainable into the future. It is even argued that sustainable development opposed to those who believe that economic activities such as business as usual, capitalist and free market economic systems are critical causes of environmental degradation.

The concept of sustainable development, however, is vague and subject to many and diverse interpretations. There are still profound differences in perspective between the richer and poorer societies of the world on issues of the environment and development. Nevertheless, the terminology has stimulated a reassessment of the meaning of development in an era full of environmental risks, in addition to becoming a bridge for efforts to set up a partnership between developed and developing countries for addressing the problems of environment and development. The crucial point now is to harmonize human societies by changing their ethical points of view, which will give pleasure in the conversion of their way of life, without the feeling of sacrifice.

(2) Environmental Impacts of Buildings

Buildings have great potential to affect global environmental issues, such as the greenhouse effect, acid rain and ozone depletion. Large quantities of carbon dioxide and other greenhouse gasses, produced by using energy during building operation and many manufacturing processes, are on such a scale that they must be taken into consideration. The modern building industry has also placed huge demands on the ecological system by using large quantities of timber during construction, leading to the depletion of forests that had played a vital role in maintaining the natural balance.

So far as carbon dioxide is concerned, about 50 per cent of all carbon dioxide emitted is directly related to our use of buildings. Many factors influence energy conservation, from the degree of thermal insulation to the efficiency of services plant and even the aspect and configuration of the building. Energy is used for the heating of space and water, the cooling of space, ventilation, lighting and so on in various buildings. Similarly, About 50 percent of the ozone-depleting chlorofluorocarbons (CFCs) is used in buildings as part of the air condition or refrigeration systems, in fire-extinguishing systems and in insulation materials throughout the world.

The construction industry is gaining a somewhat infamous reputation for causing adverse effects upon the environment, not only directly from its own activities, but also indirectly from industry it supports through its resource demands. Construction is a large consumer of resources, with massive amount of raw materials being

extracted from the natural environment, and consequently waste accumulates beyond nature's capacity. Furthermore, raw materials such as wood require energy when being converted to building components. Ecosystems are especially changed by the construction of big buildings. Concrete mass and a lack of trees have an influence on regional climate change, causing an urban greenhouse effect.

People recognize that increasing indoor and outdoor pollution including CO_2 concentration, combined with energy-saving measures like innovation in ventilation systems and tighter building envelopes, help make buildings easy concentrators of pollutants. This raises questions about what constitutes environmental health and comfort. It is also beginning to be known through research that the design, initial commissioning or lifetime maintenance of environmental performance is inadequate in too many buildings. Through this recognition, there are efforts for green architecture in modern society.

In order to satisfy residents of buildings, understanding of requirements is essential for architects. Buildings vary according to their type and their residents, so it is difficult to reach a single conclusion. Generally, building should satisfy present users as well as future requirement and avoid environmental impacts. Attributes of successful buildings are well described by Barrie Evans (1996), such as:

1. Integration of building and human systems
2. Resources and adverse impacts minimized
3. Simple, capable of upgrading, avoiding unnecessary complexity.
4. Economical of time in operation
5. Respond rapidly to change
6. Sufficient management resources for the routine and unpredictable.
7. Comfortable and safe most of the time, with rapid management backup.
8. Avoid introducing failure pathways.

The environmental design agenda has gradually been shifting away from the negative such as not using energy, not polluting the environment; to the positive, such as enjoying the letting in of more natural light and air. Comfort was often narrowly defined as the absence of discomfort. Creating green buildings requires not just higher technical standards for energy efficiency or reduced environmental impact, but green attitudes. Cultural change is needed throughout the building industry – change which affects how we design, what we design and specify, and how and why buildings are constructed. Unlike other man-made goods such as cars and televisions, buildings not only embody energy and other resources but also carry the investment across generations. It is now no longer acceptable to see buildings merely as products to be consumed and replaced within a generation. Buildings are reservoirs of compacted energy and resources handed down across centuries.

3. A TOOL FOR ENVIRONMENTAL IMPACT ASSESSMENT FOR HIGH-RISE APARTMENT (EIAHA)

Since the requirement of a proper environment/energy assessment tool for a building has been increased, there have been efforts to make a proper tool for Korean buildings. Efforts to make a proper assessment tool have been done during the last few years, by KNHC (Korea National Housing Corporation) and KIER (Korea Institute of Energy Research). However, current energy policies focus on the reduction of energy use with lack of a proper holistic assessment. The references of assessment tools described here are mainly from the case of the United Kingdom, for a better assessment tool.

The data taken here are mostly from the "Environmental standard – Homes for a Greener World" in the BRE Report (1995), a first and recent revision of BREEAM/New Homes (1991), which is one of the Building Research Establishment Environmental Assessment Method (BREEAM) series. BREDEM (Building Research Establishment Domestic Energy Model, 1985), SAP (The Government's Standard Assessment Procedure for energy rating of dwellings, 1996), a BSRIA Report, 'Environmental Code of Practice for Buildings and their services' (1994) and some 'Life Cycle Analysis' from various literatures are investigated.

The EIAHA starts with the design stage, where careful passive design can save energy while keeping thermally comfortable conditions. Passive design includes building orientation and unit plan, where effective amount of solar energy can be acquired without adding more materials. The use of sun-space for collecting winter solar heat is also an import element to reduce heating load. Passive design includes thermal insulation, where additional insulation materials are required. These materials usually embody a lot of energy, but research shows that this energy consumption can be taken off because of the savings during the building operation.

The EIAHA goes on to the construction process, where issues of materials are mainly discussed. The construction and installation stages of building have less environmental impact compared to the energy use for raw materials mining. The transportation of building materials also requires massive energy consumption, especially for heavy materials. The assessment starts with general items for building materials such as ecology and health issues, and then energy content for producing building materials, so called embodied energy, will be examined, in order to find out how much energy is required to make a building.

Energy is also used during the building operation. Energy use in the operation of apartment buildings is categorized into energy for heating, hot water and electricity. Energy for electricity involves lighting, home entertainment, lift operation, etc., as well as using mechanical cooling facilities in summer. While energy use for electricity mostly depends on the life-style of the

residents, there is a wide difference in the amount of energy use of heating according to the heating mode and the operation of a heating system. This part, therefore, mainly deals with the efficiency of a heating system, comprising heating modes and their operation.

Finally, the importance of a building's life in terms of environmental costs will be discussed. Although there are certain economical or social benefits from redeveloping existing apartment estates, there is also an enormous negative effect on the environment, through the use of materials and energy, and the production of waste. Apart from materials used and waste, which are also very important for sustainable development, energy consumption for demolishing old and reconstructing new apartment buildings is so great as to consider an alternative. The EIAHA deals with the assumption of building life with a reference of current trends. Since the life of building does not totally depend on the physical life - the life expectancy because of building deterioration -, further factors such as social and economical elements, which affect building life will be investigated along with the establishment of management systems, maintenance and repair plans.

Elements of EIAHA are shown in Table 1. There are two steps in each category, comprising eight steps. Each step has 10 credit points. Apartment buildings will be assessed Good, Medium or Bad in each step according to the credit point acquired. The main purpose of this assessment is to look at the balance of each category, rather than to calculate how many points can be acquired. The suggestions will focus on making balance on each step, instead of maximizing the total points.

Table 1. Elements of EIAHA (Environmental Impact of High-rise Apartments)

Category	Step	Element
Passive Design	Passive Solar Design	Orientation (4points) Room Arrangement (1point) Sun-space & Balcony (5oints)
	Insulation and Ventilation	U-value (4 points) Window glazing (2 points) Thermal break & condensation (2 points) Ventilation (2 points)
Building Materials	Ecology and Health	CFC-free materials (3 points) Tropical hardwood (3 points) Health (2 points) Recycled Materials (2 points)
	Embodied Energy	Establishment of the figure (4 points) Value of embodied energy (6 points)
Heating System	Heating Mode	Heating Mode (5 points) Fuel Type (5 points)
	Operation of Heating System	Control (2 points) Metering (2 points) Complaints (2 points) Equality (2 points) Comfort (2 points)
Management and Maintenance	Building Life	Life-expectation (4 points) Consideration of Easy Repair (3 points) Social Aspect of Building Life (3 points)
	Management System	Establishment of Management System (2 points) Fund for Maintenance (4 points) Repair Plan (4 points)

Although the total credits mainly means higher performance of environmentally friendly development, the points cannot indicate the absolute value for the assessment. The points taken here are, therefore, relative, which means twice of the points does not equal to the half of the environmental impact. The numbers are just a sequence of the orders of preferences. It also does not have the same gravity on each step. The intention of categorizing each step is to look at the balance of each item. The amount of total points does not always mean the order of environmental impact. The important thing here is to focus on the balance of each step

Even the credit system is not perfect because of difficulties for deciding each point, using credit points is one of the clearest ways to look at the assessment. Targets in each step can be suggested for improving the credit points.

(1) Passive Design Strategies

Passive solar design is the first step of EIAHA. All buildings have an effect of passive solar design since they collect some solar energy, unless they are completely shaded. Successful passive solar architecture has not only to combine solar heating, day-lighting and passive cooling, but has also to create good external layouts and appearance, together with pleasant internal arrangements.

Orientation is one of the simplest ways to improve the thermal environment without adding energy both for operation and construction. South-facing, which is most efficient way to accept winter sun, gets 4 points in EIAHA, while north-facing gets no points. The orientation needs to accompany room arrangement, in here one point is given in the assessment. Using balcony is good way to improve thermal performance through installing windows outside the balcony space, indoor temperature in winter will rise more properly and this will get 5 points in EIAHA

Table 2. Credit Points of Passive Design

Item		Credit
Passive Solar Design	Orientation	South - 4 points South-east, South-west - 3points East, West - 2 points North-east, North-west - 1 point North – 0 point
	Room Arrangement	Main rooms facing south, south-east, south west – 1 point Others – 0 point
	Balcony & Sun space	Balcony with sunspace window preinstalled - 5 points Balcony with sunspace, window installed later – 3 points Balcony with sunspace – 2 points Balcony only – 1 point
Insulation and Ventilation	Wall Insulation (U-value)	Less than 0.4 W/m^{2}K – 4 points Between 0.41-0.45 W/m^{2}K – 3 points Between 0.46-0.50 W/m^{2}K – 2 points Between 0.51-0.55 W/m^{2}K – 1 point More than 0.56 W/m^{2}K – 0 point
	Window glazing	Double Glazing – 2 points Single Glazing – 0 point
	Thermal break & Condensation	Outer wall insulation – 1 point Condensation-free – 1 point
	Ventilation	Cross ventilation – 2 points

In order to maintain a constant temperature within a building, it is necessary to restrict the rate at which heat energy is exchanged with the surroundings. Thermal insulation is a major factor in reducing the loss of heat from buildings, or in reducing the flow of heat when temperature outside is greater than temperature inside.

In EIAHA, thermal insulation will have 8 points, comprising 4 points for U-value for wall insulation, 2 points for window glazing and 2 points for concerning thermal break and condensation. Ventilation has 2 points for concerning cross ventilation. The importance of cross ventilation will be increased, but most energy for temperate weather region is used for heating, on which thermal insulation has a great effect.

(2) Building Materials

Building materials affect the environment in different ways. Some affect the environment within the buildings, including the use of asbestos products and solvent-based paints. For a sound environment within a building, materials should be clean and contain no pollutants or toxins, emit no biologically harmful vapors, dust, particles, or odors. They should also be resistant to bacteria, viruses, moulds, and other harmful micro-organisms, which will make the residents uncomfortable or even ill. All materials should also be radioactively safe and should not emit any harmful levels of radiation. In these technology-dependant societies, we need to be more careful to protect the Earth when choosing building materials. There have been some efforts for protecting the natural environment as well. New buildings will tend to be longer lasting and lower in energy use. They are likely to be made of simple natural materials such as wood and stone, rather than aluminum and plastic. Internal finishes and furnishings will be based similarly on natural materials and timbers.

Table 3. Credit Point of Building Materials

Item		Credit
Ecology and Health	Insulation	All CFC-free insulation – 3 points CFC blown insulation less than 10% – 2 points CFC-blown insulation between 11-20% – 1 point Others – 0 point
	Wood	Tropical Hardwood less than 10%– 3 points Tropical Hardwood between 11-20% – 2 point Tropical Hardwood between 21-40% – 1 point Otherwise – 0 point
	Health	Asbestos free – 1 point Solvent-based point free – 1 point
	Recycled Materials	More than 50% - 2 points More than 25% - 1 point
Embodied Energy	Concern	Establishment of Embodied Energy Figure - 4 points Concern of Energy Saving for Materials – 2 points
	Value	Less than 1,000 KWH/m^2 – 6 points Between 1,001 – 1,200 KWH/m^2 – 5 points Between 1,201 – 1,400 KWH/m^2 – 4 points Between 1,401 – 1,600 KWH/m^2 – 3 points Between 1,601 – 1,800 KWH/m^2 – 2 points Between 1,801 – 2,000 KWH/m^2 – 1 points More than 2,000 KWH/m^2 – 0 point

In EIAHA, three points are given to the concerning ozone depletion, by looking at CFC blown insulation. Another three points are given to the conservation of hardwood in tropical region. Two points are allocated to health issues, concerning of asbestos and solvent-base paint free. The remained two points are given to the issues of recycling of building materials.

Energy used for buildings is vital for the environmental assessment of buildings, both in energy used for operation and the embodied energy of buildings. The energy required to make a building includes the energy require to extract, process, transport and assemble the materials of which it is made. Since the 1970s, attempts have been made to quantify the embodied energy of a range of different materials, constructions and building types. These studies have suggested that the energy used to make a building can represent many times the energy used in a year of operation.

Six points are allocated to the actual embodied energy value in the EIAHA. The remained four points are concern of establishment of embodied energy figure.

(3) Energy Consumption During Building Operation

Using energy for building operations is another category relevant to the environmental design of buildings. Although there are many activities, which require energy such as lighting, cooking and entertainment using electricity, energy use for thermal comfort is the biggest portion in most buildings in most areas, and has great potential to be reduced

Table 4. Credit Point of Heating System

Item		Credit
Heating Mode & Fuel Type	Heating Mode	District Heating with CHP installed – 5 points District Heating without CHP installed – 4 points Central Heating – 3 points Individual Boiler – 1 point Others – 0 point
	Fuel Type	Gas and Garbage – 5 points Gas, Oil and Garbage – 4 points Oil and Gas – 3 points Oil, Gas and Coal – 2 points Oil and Coal – 1 point Coal – 0
Operation of Heating System	Control	Easy control of the system – 2 points
	Metering	Well established billing system – 2 points
	Complaints	No complaints from residents about operation – 2 points Less than 5 percent complaints – 1 point
	Equality	Thermal equality between floors – 2 points
	Comfort	Even room temperature through underfloor heating – 2 points Efficient distribution of radiators – 1 point

In EIAHA, two different steps are assessed. The first step concerns heating mode and fuel type; five points for the heating mode and the remained five points for fuel type. The other step concerns about the operation of heating system. There are five items, each of them has two points. These are easy control of the system, billing system through efficient metering, complains, thermal equality between floors and comfort.

(4) Management and Maintenance

Even after completion of construction, a building has the potential to affect the environment. Building cannot

stand with the same condition forever, and finally they come to their final stage, demolition point. Demolition and reconstruction again have serious effects on the environment, by using massive amounts of raw materials and producing waste. Good maintenance management with proper long-term repair plans and adequate financial arrangements is required for longer life spans The process of repair also has the potential to degrade the environment. Demolition, as the final stage of a building's life, can be a starting point for a new life, if there will be a new building on the same site. Reuse of materials from old buildings when new development is launched plays an essential part in preserving raw materials. It is difficult to say how long should a building last. If concerned about the life of concrete, high-rise apartments may last about 60 years. In EIAHA, if life expectation of an apartment building is more than 60 years, which is almost as long as its physical life, 4 points will be allocated. Apart from life expectancy, 3 points are allocated to the consideration of easy repair, and the other 3 points are allocated to the social aspect of building life.

Building maintenance is defined as work undertaken in order to keep, restore or improve every facility, i.e., every part of a building, its services and surroundings, so to currently accepted standard and to sustain the utility and value of the facility. The maintenance budgets are prepared using the master action plan based on the building inspections and information from the previous year's building operational expenses. For many materials and components, maintenance work or replacement needs to be done as soon as the damages become evident if a small defect leading to a complete failure would be avoided. In the last step of EIAHA, management with proper maintenance plan will be assessed. It deals with the establishment of management system (2 points), fund for maintenance (4 points) and proper repair plan (4 points).

Table 5. Credit Point of Management and Maintenance

Item		Credit
Building Life	Life Expectation	More than 60 years – 4 points Between 50-59 years – 3 points Between 40-49 years – 2 points Between 30-39 years – 1 point Less than 29 years – 0 point
	Consideration of Easy Repair	Easy Separation of Pipes – 2 points (One for heating, one for others) Easy Testable for Main Structure – 1 point
	Social Aspect of Building life	Resident's life expectation of building over 50 years – 1 point No intention of redevelopment by construction companies within 50 years – 1 point Governmental encouragement of building life over 50 years – 1 point
Management System	Establishment	Establishment of management system – 2 points
	Fund for maintenance	Enough for Long-term Repair plan – 4 points Established but not enough – 2 points Not established – 0 point
	Repair Plan	Life-time repair plan – 2 points Year-by-year repair plan – 2 points

4. APPLICATION OF EIAHA TO CURRENT HIGH-RISE APARTMENTS

This section applies the EIAHA to the current development of high-rise apartments. The assessment mainly applies to the five apartment estates in Pundang New Town. Two of them are built by the Korea National Housing Corporation (KNHC) and the rest by private companies. Most of the design and construction methods in apartment developments are quite similar, so it is sufficient to focus on a few estates as a representative of the whole apartment construction industry. These five estates, which were developed in the late 1980s and early 1990s, are appropriate examples for assessing the trends of current apartment developments.

Passive designs of apartment building in five estates are almost identical. The orientation is strongly related to the shape of each estate with the preference of facing to south, south-east or south-west. Insulations are installed at the minimum requirement of the regulation. Cross-ventilation is considered in the unit plan avoiding overheating in hot-humid summers. Passive design is generally well established in the case of orientation and room arrangement, but there is a space of improvement in the area of installation of glasses outside balcony area, which can reduce further energy requirement. There is a need to improve the standard of insulation (U-value, or K-value) for acquiring a proper thermal insulation. Insulation is usually installed inside of the structure, which may cause thermal break, so change of the insulations on the outside wall is suggested.

The thorough investigation of the assessment of building materials took from the case of KNHC (Korea National Housing Corporation), one of public construction companies in Korea. The materials used by private companies tend to be slightly more luxurious, which may require more cost both in money and energy, but just a minor difference because all building have almost the same structure. The issue of building materials in terms of the environment has not well been recognized in Korea. However, the recognition of global environmental disorder such as ozone depletion and loss of tropical forests leads to think of wise use of building materials. The efforts for using re-cycled materials have also been increased, but use of them is not still sufficient. The importance of the embodied energy of building materials is not widely known, which results a requirement of significant improvement in this area.

The assessment of heating system for the five estates is the same since all of them supply heat and hot water through one district heating system power station. This power station saves about 30% of energy and reduces the same proportion of CO_2 emissions, compare to a central heating system. There are just a few differences in the assessment of operation of heating system according to estates, since the distribution system of heat supply is shared by all the estates in Pundang New Town. The difference here is complaints of heating bill in an

apartment estate, where there has been a failure of the metering system.

Assessment of building life is difficult, because most of them are still less than 30 years old. The assessment, therefore, is merely a guess work. Based on current redevelopment of low- or medium-rise apartment buildings, where only 20 years-old buildings are destroyed for redeveloping the existing estates converting into more dense estates, the life of high-rise apartment buildings can be assumed around 30 years. One of the problems of the short life may be that there is no responsibility for construction companies after 20 years of the construction, and management of the estate is handed over to management offices in one year. The assessment of management and maintenance of the EIAHA represents that there is a room for improving the condition of building, by taking more careful consideration of maintenance programs. This consideration may also help the building's longer-life expectancy.

Through the application of each step of EIAHA, the character of high-rise apartment developments in each step has been searched. Here, the holistic view of the character is described through the summary of the application of EIAHA into current high-rise apartments.

Table 6. Summary of Credit Points and Grade of Current High-rise Apartment Development by EIAHA

Step	A	B	C	D	E	Average	Grade
Passive Solar Design	7	8	7	7	8	7.4	M
Insulation and Ventilation	7	7	7	7	7	7.0	M
Ecology and Heath of Materials	8	7	7	6	7	7.0	M
Materials' Embodied Energy	5	4	2	3	5	3.8	B
Heating Mode	8	8	8	8	8	8.0	G
Operation of Heating System	9	9	8	7	9	8.4	G
Building Life	4	4	2	2	2	2.8	B
Management System	6	7	7	8	7	7.0	M

G: Good, M: Medium, B: Bad

The issues mentioned here interrelate with each other, and efforts towards a solution are suggested to have a good balance between steps. Each item has 10 points. 8 or more points ranked 'Good' and 5 or less points ranked 'Bad'. The point between Good and Bad ranked 'Medium'. While the item ranked 'Good' and 'Medium' confirm steadily improving standards, further attention to those assessed as 'Bad' (Embodied energy of building materials and building life) is urgently needed.

5. CONCLUSION

Through the assessment of apartment estate development, future development for sustainable environment is suggested in two broad categories – embodied energy of building materials and life-cycle planning.

While careful consideration of building orientation and unit plan for passive solar design and efficient heating systems for reducing thermal operation are well established, the importance of embodied energy of building materials both for initial construction and during the maintenance procedure is not yet recognized. As the value of initial embodied energy in Korean apartments is much higher than in the United Kingdom, taking the embodied energy into account for future construction is strongly recommended in order to minimize environmental impact from the building industry.

Short life building cost more not only in economic terms but also environmental terms. Use of energy and raw materials, as well as waste production, is inevitable during the construction and demolition process. The amount of energy used for construction is equivalent to that required for many years' building operation. The life of building is influenced by the initial design and construction, but the life can also be extended by proper management and maintenance. Through employing proper long-term maintenance programs by management offices, buildings may extend their life. Social recognition of longer-life buildings is very important, since redevelopment has been done in some apartment estates where there is no structural defect. People should recognize the great impact on the global environment, which comes from the reconstruction of old apartment buildings.

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