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PROMOTION OF ENERGY EFFICIENT DESIGN□ A CASE STUDY IN CHINA

Qi Bao
PhD Candidate, Department of Building & Real Estate, The Hong Kong Polytechnic University, Hong Kong

Liyin Shen
Associate Professor, Department of Building & Real Estate, The Hong Kong Polytechnic University, Hong Kong

ABSTRACT
Energy is the key to human sustainability. The efficient use of energy has become an important worldwide issue as the sustainability of the energy particularly those non-renewable energy resources is under the threats of being exhausted in meeting the process of fast economic development. Furthermore, the ever-increasing waste products due to inefficient energy consumption are causing globally environmental problems. It presents the urgency for industries to seek for energy efficient consumption measures in their economic activities. The construction industry as a major energy consumer has the liability to make contributions towards this mission. Project design is considered the most important stage in contributing to energy saving as it can determine ways of consuming energy during a construction product's life cycle. Energy efficient design in construction project is even more important in developing countries such as China where energy-use efficiency in construction products is low and at the same time great amount of construction activities remains for coming years. This paper examines the ways of applying energy efficient design in China and identifies the existing problems and the areas where energy saving improvements can be achieved. Better energy consumption measures are identified for making improvements by referring to the advanced practices of other countries.

KEYWORDS
Energy Efficient Design, Energy Saving Measures, China

1. INTRODUCTION

The issues concerning effective consumption on energy have been attracting global concerns in line with people's recognition of sustainable development. Significant researches have been devoted to finding energy saving solutions. Such developments are built up on the two typical scenarios: firstly, the continuing process of industrialization and urbanization are consuming at high speed the energy sources particularly those non-renewable environment resources; secondly, the waste by-products generated from energy consumption have become the main pollutants to the environment. It is responsibility of all industries including construction to engage an appropriate practice of

protecting the environmental resources thus, protecting the sustainability of human future. The adoption of effective energy consumption measures is considered one of the important approaches in contributing to the mission of sustainable development. Jackson (1996) suggested that the practice of energy conservation could reduce both the energy demand and the levels of various pollution emissions. The promotion of effective energy consumption in construction industry is considered particularly important as the industry is a major energy consumer. Best (1997) indicated that the energy for building sector accounts for around one third of the delivered energy in most countries and highlighted the good potential of achieving energy saving from the practice of construction architects.

Effective energy use is described as a reduction in the energy intensity of a given activity by reducing the contents of the activity or changing the specification of the activity (Langston, 1997), namely, reducing the energy demand for operating the activity and improving the way of using the energy in operating the activity. Referring to a building, effective energy use concerns its whole life cycle. Various types of energy are consumed through all stages in a building's life cycle, thus energy saving is concealed at all the stages. Project design is considered as the most important stage in contributing to energy saving as it can determine way of consuming energy during a construction product's whole life cycle. Existing research findings suggest that the initial design of a building has largest influence to both energy saving and the level of energy efficiency throughout the building's life cycle (Lauge-Kristensen, 1997; Fang, 1999; CIBSE, 1998). Typical factors influencing the efficiency of energy use for building include the building's location, orientation, building materials, landscape features, surrounding area, and the position and types of its adjacent buildings. It is the practice of project design that can improve the efficiency of using energy by adjusting these factors. For example, the proper design on building's orientation can lead to good natural ventilations, thus reducing the building's operational energy for ventilating. Rima (1997) indicated that if 60% of a building's windows correctly oriented, a house's heating load will be reduced by 25%.

The promotion of energy efficient design is considered particularly significant to those developing countries such as China where huge amount of construction activities are expected for now and the near future. This paper focuses on studying the design practice incorporating efficient energy use measures in China. A comparative examination on the practice between China and other countries will be conducted. Such examination will lead to the proposal of better measures for improving the energy efficient design in the promotion of project design in China.

2. METHODS DEVELOPED FOR ENERGY EFFICIENT DESIGN

The recognition of energy efficient usage in operating a building across its life cycle have attracted both academic and practical interests since 1950s with significant development of various methods for energy efficient design. Watson (1983) suggested that although technological advances in energy saving had been achieved among the existing research works, the wisdom of designing with incorporating climate and surrounding environment was often ignored. For example, the technology of using solar energy in the operation of a building was developed in the early 1970s, and it has also been incorporated into the design practice. However, the design for using solar energy usually only considers the functions heating or cooling without considering the impacts of the variations of environmental climate on the operation of the solar energy system. In fact, if the solar energy system is not designed to adapt seasonal climates, more energy will be employed to adjust the heating or cooling conditions of the building. For example, energy will have to be used to provide cooling if overheating is induced by the solar energy system that is not properly designed.

Following the development of using solar energy in building, Watson (1983) introduced the methodology of 'climatic design'. This incorporated the characteristics of climatic changes with applying energy in operating building's functions. This methodology brought the development of the previous design practice that normally emphasizes using energy for single function, for example, solar energy for heating. Both practice and research of using energy more effectively at project design stage has made significant progress aiming for an energy saving building across its life cycle and at same time providing comfortable and environmentally friendly living surroundings.

Nevertheless, design practice for building like other economic activity has to consider both the cost and the function of the building. An energy efficient building can be defined as, a building which uses minimum energy whilst

providing its required functions whilst being able to respond to the changes of climatic conditions in a way that energy can be saved. Simply, energy efficient design is the optimal balance between energy saving, overall cost saving and effective functions. This balance can not be gained without incorporating broad based issues such as the building's orientation, building's overall layout, through to the detail design specifications such as the positioning of the light switches or thermostats.

It is well known that the Chinese construction industry is a low energy-efficiency industry whilst it remains a major energy consumer, thus engaging an energy efficient design practice is the key to sustaining the country's development. The experiences in practicing energy efficient design gained from those developed countries are valuable to China's improvement. The following section is going to discuss the key factors incorporated in the process of engaging energy efficient design, and comparison in dealing with these factors between China and developed countries will be conducted.

3. FACTOR ANALYSIS TO ENERGY EFFICIENT DESIGN

Roaf (1992) pointed out that all design related activities affect the energy consumption efficiency, and the identification of the key factors attributing to energy efficient design is considered the most important in order to apply a proper design process. For this, numerous studies have presented a number of factors (Roaf, 1992; Rima, 1997; Fang, 1999). Based on these studies, the major factors can be grouped as orientation and site layout; the layout of building and internal planning; infiltration and ventilation; insulation; passive solar design, the selection of heating, hot water systems, and lights and appliances.

3.1 Orientation and Site Layout

A building's orientation and site layout decisions are normally decided upon during the early design process and have significant effects on overall energy use efficiency as they determine the way of using energy across the building's life cycle. For example, the design decisions can be made for allowing the use of sunlight for heating in the winter or cold weather, and on the other hand allowing the wind flow for fresh air ventilation in the summer thus the reduction in using energy for cooling can be achieved.

3.2 The Layout of Building and Internal Planning

It is usually considered that building layout influences the efficiency of using energy via: shape and the orientations of windows. Different shapes and windows orientation of building will present different thermal response, insulation, glazing, ventilation and effects of day lighting (CIBSE, 1998). In general, the building in compact forms has a relatively small exposed surface area for a given floor area, thus it can reduce the influence of the external environment. For example, a cube which is in compact form will result in the minimum practical surface area thus it can induce the minimum loss of fabric heat (Roaf, 1992).

3.3 Infiltration and Ventilation

Traditionally, infiltration has been relied on to provide air ventilation, but this mechanism will bring more energy consumption when air conditioning system is employed as the air condition system can provide ventilation and more infiltration can only serve as air leakages. Thus the key to improving the efficiency of energy use is to reduce infiltration to a minimum and to provide a controlling mechanism, which allow fresh air for ventilation.

3.4 Insulation

Proper insulation is important for regulating the internal temperature of a dwelling, and insulation is typically applied to walls, floors, and ceilings that conduct heat with the surrounding directly. Lauge-Kristensen (1997) indicated that the main areas including heat loss in a building are, in descent order, the roof, walls, floors, windows

and ventilation/infiltration. Therefore, significant contributions to energy efficiency can be achieved through the proper insulation to the roof, walls, floor and windows. The typical measure for assessing the ability of a building section to allow heat flow is the U value of the building section, the lower this value is, the higher the insulating capacity.

3.5 Solar Design

A design that makes use of solar power is a solar design. Roaf (1992) proposed four techniques which were employed in solar design: allowing building to face south and avoid overshading; placing the glazing on the south side; positioning the window in a way that the window will not be obscured with blinds or net curtains; improving the performance of the glazing. The application of these techniques can make substantial contributions to energy saving. Roaf (1992) reported that approximately 24% of the energy used for housing could be met by solar gains in applying these techniques.

3.6 The Selection of Heating, Hot Water Systems, Lights and Appliances

While some buildings are well designed with good insulation, it still has low energy saving efficiency because of improper choice of heating system and other accessorial equipments. Roaf (1992) suggested that the poor choice of these accessorial systems and the type of controls can easily double the running costs of a house. The potential for reducing energy costs is considered enormous. Lauge-Kristensen (1997) argued that the designers can contribute significantly in cutting energy costs of using electric lighting by specifying low energy fluorescent lamps instead of the common tungsten lamps, and it is reported this replacement can result in 75% energy saving.

The identifications of the key factors affecting the efficiency of using energy provide the basis for conducting the comparison of energy-saving design practice between China and those developed countries. The application of consideration of the impacts of the above factors in design practice is different among different countries or regions, as the consideration will have to reflect the social and economic environment of the countries concerned. Next section will focus on the examination of energy saving design practice in China.

4. THE DEVELOPMENT OF ENERGY-SAVING DESIGN PRACTICE IN THE CHINESE CONSTRUCTION

It is reported that the energy consumption in construction activities accounts for 20-25% of all the energy consumed in China, and the energy utilization efficiency is 10-15% lower than that in developed countries (ACEE, 2000). The improvement of energy using efficiency for buildings in China has been evidenced since 1980s. In particular, good development of heating systems for residential buildings in Northern areas has been made. According to ACEE's report (ACEE, 2000), the development of energy saving design in China has been through four stages:

(a) Development of the techniques and establishment of standards during 1980 to 1987.
In this stage, 'energy efficient design standards for civil buildings' was issued by governmental department on August 1st 1986. At the same time, significant research works on heating and air-conditioning energy efficient design standards in hotels were conducted.

(b) Testing the standards for energy efficient buildings during 1988 to 1994.
During this stage, a number of experiments on designing energy efficient buildings were undertaken, and demonstrations were set up in different cities accordingly. In 1993 September, the Ministry of Construction issued the first formal standards 'heating and air-conditioning energy efficient design standards for hotels', which represents the start of applying energy-saving design practice for commercial buildings in China.

(c) Establishing laws imposing the implementation of energy efficient design practice during 1994 to 1996.
In 1994, Ministry of Construction established an office overseeing the implementation of energy efficient design. The policy set in state's Ninth Five-Year Plan and Plan for 2010 specified specific objectives, and emphasized the

implementing process of the energy saving design. In line with these polices, 'Energy efficient design standards for civil buildings' was developed, aiming to achieve 50% energy saving.

(d) Full implementation of energy efficient policies and regulations from 1996. This stage has been implanting various policies in order to achieve 50% energy saving in developing new building projects.
Over the previous twenty years, energy efficient buildings have gained good development. Until 1995, buildings built according to energy efficient criteria amounted to 40 million m^2 (ACEE, 2000). Based on the assessment on previous progress in practicing energy efficient design, ACEE's report suggested four aspects from where further improvements in energy efficient design can be achieved, including: i) Development of building technology; ii) Further research on mechanisms of energy efficient buildings for different localities; iii) Research on energy efficient building material; and iv) Research on energy efficient heating system.

From the above, it can be concluded that the promotion of developing energy efficient building in China has achieved good progress although the development only started recently. This development has been driven by establishing a set of proper design standards which specify the details of energy saving methods. Over the previous years, building design standards in China have been improved substantially in response to the energy saving mission and public demand for lower running and maintenance costs. Compared with those developed countries, China has a short history in developing energy efficient design. On the other hand, the huge housing works in the coming years in China request the comprehensive and effective application of the new design methodology. It presents the opportunity for overseas professional who has built up good experience and skills in conducting energy efficient design.

5. CURRENT PRACTICE OF PROMOTING ENERGY EFFICIENT DESIGN IN CHINA

In order to examine the current practice of promoting energy efficient design in China, a constructive survey has been conducted in this study. Survey questionnaires were designed and presented mainly to architects who have significant practice experience in building design. The questionnaires concern three main parts: (a) the current situation of energy efficient buildings in China; (b) the measures adopted for incorporating the principle of energy efficiency in the design process and (c) the barriers to the promotion of energy efficient buildings in the design stage. Each part of the questionnaire consists of a number of specific questions, and following tables present the sample of the questionnaire.

Part A of the questionnaire was designed to generate a general opinion about the current situation (CS) of engaging energy efficient building in China compared with developed countries and areas. Respondents were requested to indicate a choice among five subjective indications to express their opinion on current situation of China. The five indications are very good, good, average, poor and badly behind.

Part B of the questionnaire was designed in a table format as shown in Table 2. There are a number energy saving measures applicable in design stage, such as the choice of energy efficient materials, the layout of building, orientation, insulation and so on. Existing publications have identified a number of energy saving measures (ESM) to achieve energy efficient in design process (Roaf, 1992; Lauge-Kristensen, 1997; CIBSE, 1998; Fang, 1999). Based on these literatures, 12 key factors affecting the energy consumption were selected and presented to respondents, shown in Table 1:

Table 1: Energy Saving Measures Adopted in China Today

ESM-a	Plane structural design
ESM-b	Buildings figure
ESM-c	Building volume
ESM-d	The space between buildings
ESM-e	Orientation
ESM-f	The window design
ESM-g	The materials' choosing
ESM-h	Making use of solar energy
ESM-i	Greening for building
ESM-j	Improve insulation
ESM-k	Reducing the glass area of façade
ESM-l	Shading devices

Part C of the questionnaire was designed to identify the barriers affecting the promotion of energy efficient design, and five questions are included as shown in Table 2.

Table 2: Barriers Affecting The Promotion Of Energy Efficient Design

B-a	Improper perception on high cost of developing energy efficient buildings
B-b	Incomprehensive understanding of the economic benefits of energy efficient buildings
B-c	Lack of policies for enhancing the implementation of energy efficient design
B-d	Lack of driving force form buyers market
B-e	Lack of enough energy saving technologies

The target respondents were selected from major design institutes in Beijing city and Harbin city. 360 questionnaires were sent and 264 effective responses were received. The undertaking of the survey was assisted by governmental departments (Ministry of Construction), and professionals in Universities (Harbin Institute of Technology, Tsinghua University) in providing advice and distributing questionnaire. Survey results to part A, part B and part C are presented graphically in Figure 1, 2, and 3 respectively:

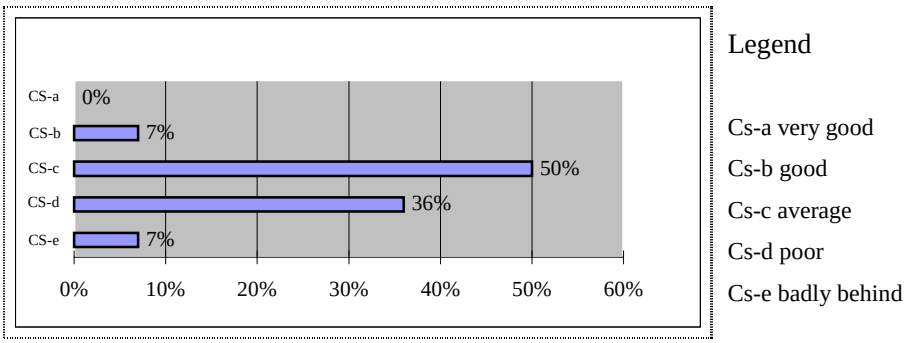

Figure 1: The Current Situation Of Developing Efficient Buildings In China

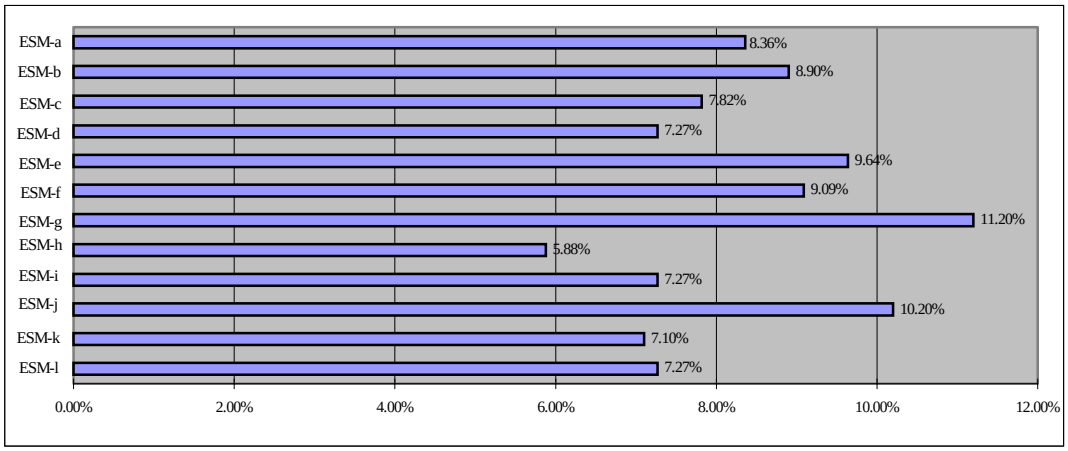

Figure 2: Ranking Of Significance Among Energy Saving Measures

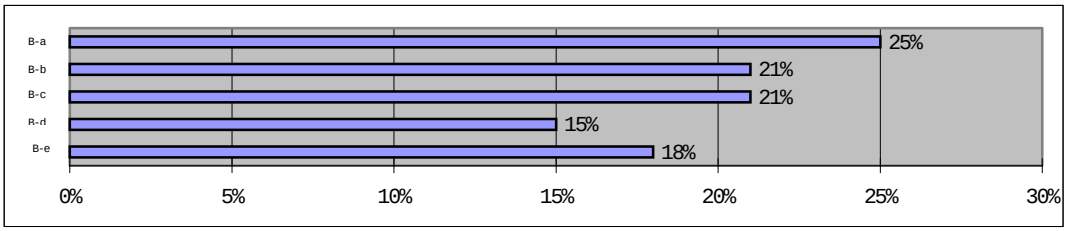

Figure 3: Ranking Of Significance Among Barriers To The Promotion Of Energy Efficient Buildings

6. ANALYSIS TO THE SURVEY RESULTS

The survey results provide valuable information for understanding the development of energy efficient design practice in the current Chinese construction industry. Barriers affecting the promotion of energy efficient design have been identified. The results shown in Fig 1 demonstrate the profile of the general opinion about the progress of implementing energy efficient design in China. Although 50% respondents consider such progress as normal, there are more respondents considering poor progress than those scoring good progress with the practice. This is considered largely due to late development of energy efficient design practice in China.

The survey results shown in Fig 2 indicate the ranking of the significance among those factors affecting the efficiency of energy consumption in project design stage, and those important factors include the choice of energy efficient materials, improvement of insulation, the building's orientation, the orientation and layout of window. This identification is similar to those findings obtained from developed countries (ACEE, 2000).

From the survey results, the major barriers affecting the promotion of energy efficient design include improper perception on high cost of developing energy efficient buildings, incomprehensive understanding of the economic benefits of energy efficient buildings, lack of policies for enhancing the implementation of energy efficient design, lack of energy saving technologies and lack of driving force from buyers market. The results indicate that practitioners do not fully understand about the benefits of energy efficient design practice, which limits the promotion of advanced practices. According to Fang's (1999) study, the education on promoting energy efficient design is well understood in developed countries, thus the project clients in these countries know the benefits of energy efficient design and are willing to implement the practice. To improve the energy efficiency in operating buildings, a combined effort is needed from governmental departments, investors and construction practitioners.

7. CONCLUSION

Through reviewing the principles of energy efficient design in developing buildings, this paper discusses the development of adopting energy efficient design in China. The discussion presents the facts that China has been through four stages in developing energy efficient design practice, namely, development of the techniques and establishment of standards, testing the standards for energy efficient buildings, establishing laws imposing the implementation of energy efficient design practice, and full implementation of energy efficient policies and regulations. The survey conducted in the paper concludes that the level of the implementation of energy efficient design in China is still far behind from the practice of developed countries. The key effective measures for implementation are identified as similar to those findings obtained from those developed countries. However, barriers exist in applying these measures in the Chinese practice, and the major barriers identified in the survey mainly concerns the late start and special history of the Chinese construction, such as improper perception on high cost of developing energy efficient buildings, lack of policies for enhancing the implementation of energy efficient design and so on.

The findings in this study provide useful references in understanding the practice of energy efficient design in China. The identification of barriers contributes valuably to the effective application of various design measures. Furthermore, the large amount of building works predicted for the coming years in China present good business potential for those overseas professionals who have built up good strength and experience in implementing energy efficient design methodology.

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