CHAPTER 3

BUILDING ENERGY PERFORMANCE STANDARDS

ll signs point to the conclusion that energy standards, particularly for non-residential buildings, will play an increasingly significant role in the future of national and possibly international energy-efficiency policies." – (Janda and Busch, 1994)

Building energy study in this thesis is tandards-oriented' as the author believes that the knowledge about building energy performance should be injected into building energy standard (BES) if the maximum benefits are to be harvested for the community. This chapter presents a general background of BES, explains the major efforts in the world on BES development, highlights significant implications for Hong Kong and analyses useful experience for setting out an effective BES.

3.1 Background

The general background of BES is described; the major barriers to building energy efficiency are outlined; the role of government is discussed.

3.3.1 What are BES?

Building energy standards provide a degree of control over building design practices and encourage awareness of energy-conscious design *. The historical function of building codes has been to ensure health and safety of inhabitants, but recently they have been directed at energy efficiency as well (U.S. Congress, Office of Technology Assessment, 1992). Thermal insulation standards developed in countries with cold climate can be considered as the earliest generation of BES (Billington, 1975). It is difficult to define BES since no established nomenclature clearly identifies what policies might be considered nergy standards’ (Janda and Busch, 1994). Depending on the country, BES may be contained in one document, be part of another larger document (such as the general building code), or may comprise several documents. From the survey results of Janda and Busch (1994), there are currently at least 40 countries with some form of standards for energy use in buildings. Levine, *et al.* (1995) also discovered that countries on almost every continent were now in various stages of developing, improving, and expanding their BES .

Prescriptive and performance approaches

Generally, two approaches are taken to determine the acceptance criteria for BES (Baird, *et al.*, 1984, pp. 48-51):

- *Prescriptive approach* – It specifies for each building component the minimum requirements to satisfy the standard, such as minimum insulation levels and equipment efficiencies. Prescriptive standards are simple to use, but their effect on building energy conservation is indirect since none of them deals with the building as a whole (Baird, 1979). Traditional BES are often prescriptive in nature.

- *Performance approach* [†]– Performance standards set a maximum allowable energy consumption level without specification of the methods, materials processes to be employed to achieve it, but with a statement of the requirements, criteria and evaluation methods (Marshall and Petersen,

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[*] The term ‘standard’ or ‘standards’ is used in this thesis to indicate energy standards, codes, regulations and guidelines.

[†] Performance approach is defined as the practice of thinking and working in terms of ends rather than means and is concerned with what the building (or building product) is required to do, rather than prescribing how it is to be constructed (Baird *et al.*, 1984).

1979). The onus will be on the designer to present a design solution together with appropriate predictive evidence of its energy behaviour.

Basic functions of BES

Building nergy performance' standards are the most important manifestation of the concerns on building energy use. The basic functions of BES, as the author thinks, include:

- To raise concern and awareness of building energy conservation.
- To promote energy-efficient design and operation in buildings.
- To promote the development of energy-conservation products and service industry.
- To help achieve improved and more uniform good energy performance in new buildings for meeting energy policy goals.
- To define a baseline of energy performance for incentives or any other energy programmes.

Although the benefits of efficient energy use are realised by most people, the marketplace and conventional government policies are usually structured in a way that encourages wasteful use of energy, not efficient use of all available energy resources (Alliance to Save Energy, 1993).

3.1.2 Barriers to building energy efficiency

The factors limiting adoption of energy efficiency technologies have been described by Levine, *et al.*, (1992, pp. 47-59). The obstacles and barriers to delivering energy efficiency to the market were also discussed in many literature, such as Hillman and Bollard (1985, Chp. IV), Anderson (1993), Howarth and Andersson (1993), Fisher and Rothkopf (1989), and Fitzsimons (1990). In short, the difficulties can be categorised into three main areas:

- *Separation of interests* – Building developer usually bears the costs with efficiency investment while savings accrue to building owner or tenants.

Unless for an owner-occupied building with energy-concerned users, energy conservation is not taken as a major item in the overall budget.

- *Imperfect market structure* – The business market mechanism for energy efficiency is imperfect with various time and capital constraints. Howarth and Andersson (1993) pointed out that problems of imperfect information and transaction costs may bias rational consumers to purchase devices that use more energy. Fitzsimons (1990) found that the market alone will never ensure optimum investment in energy efficiency.

- *Social and institutional barriers* – Blumstein, *et al.* (1980) found that it is essential to consider not only the efficiency of strategies in achieving the goal of energy conservation, but also their impact on social and economic goals. The lack of institutional support and co-ordination at the community or national level is often a critical factor undermining the effectiveness of energy conservation strategies.

Obstacles in Hong Kong

In addition to the general difficulties, there are eight obstacles peculiar to Hong Kong which is worth attention:

a) *High land value and small energy costs* – Costs associated with land element often work against energy conservation in Hong Kong as the percentage value of energy costs is small when compared with building rental value. Blake (1991) found that because of the substantial element of land value, building owners or users became disinterested in saving energy cost.

b) *Lack of long-term policy* – It has been criticised that Hong Kong government plan to promote building energy conservation was sketchy, lacked sound details and long-term strategies (urbing energy appetite”, 1990). Hills (1994) reported that no department within the government was specifically charged with the responsibility for energy planning and Hong Kong did not have an energy policy as such.

c) *Building regulations mention very little about energy efficiency* – Before 1995, no provisions were present in the Building Regulations of Hong Kong (Hong Kong Government, 1991) to promote energy-efficient building design and operation. A new *Building (Energy Efficiency) Regulation* has recently come into operation in July 1995 (Hong Kong Government, 1995), but not many important aspects have been addressed.

d) *Building developers and tenants not interested in energy conservation* – The developers constructing buildings are more concerned with making them attractive for sale or sub-letting than in investing in energy efficiency designs. Tenants of leased commercial buildings have little incentive to conserve energy since they are often charged a fixed sum on a superficial area basis for the landlord utilities (Roper and Lam, 1991). Braga (1993) complained that everyone goes for short term gain (in Hong Kong). Energy profligacy of buildings is seldom considered seriously.

e) *Power companies not encouraged to end-use energy efficiency* – Under the current *Schemes of Control Agreements* (Hong Kong Government, 1982), the two power companies in Hong Kong, being private enterprises, are not rewarded for selling efficiency since their ermitted rate of return' is related to the net fixed assets of their generating plants and other installations, not the energy saved. Their tariff structures do not attract consumers to adopt consumption reducing and load shifting strategies.

f) *Incorrect attitudes and misunderstandings* – Roper and Lam (1991) found that in Hong Kong electricity is perceived as a commodity rather than a non-renewable resource. People are generally wary of making investment in energy conservation measures because of the lack of understanding and the uncertainty of paybacks. Some people are afraid that energy conservation will cripple the growth of the economy.

g) *Lack of awareness* – Usually no one assumes a full responsibility of monitoring energy consumption and improving its efficiency in buildings. People with day-to-day responsibility for energy use rarely have the power to make investment decisions on energy efficiency whereas building owners are not aware of the true value of energy conservation.

h) *Lack of information* – There is very little information about the energy use in buildings and how the building performance can be measured and analysed in Hong Kong. A general lack of interest in feedback from existing buildings hinders collection of energy and building data (Chan, 1994). Some building owners are even afraid of being publicised on the inefficiency of their buildings – the efficiency irony (AAC, 1992).

3.1.3 The role of government

Energy standard is an effective instrument to help overcome barriers and achieve energy efficiency goals of a country. However, what appears now is that the benefits of conservation are clear, but the proper role for government is hotly debated (Hirst, Fulkerson and Carlsmith, 1981). The role of government action in improving building energy efficiency has been discussed elsewhere from national and international points of view (International Energy Agency, 1992; Warren, 1991; Hirst, Fulkerson and Carlsmith, 1981). The prevailing conditions indicate that reasons of economy alone will not provide sufficient impetus for the widespread acceptance of energy efficiency techniques. Without the support of local governments, the energy savings envisioned with BES will not materialise (Wirtshafter, 1988).

Voluntary or mandatory

The question of whether BES should be mandatory or voluntary is controversial in every part of the world [*]. There is not any hard and fast rule about which one is more effective than the other since the success of BES depends not only on how it is designed and codified but also on how it is implemented and publicised. Protagonists of mandatory approach argue that voluntary guidelines will not ensure high building energy efficiency. The

[*] 'Mandatory' means everyone MUST comply in some ways or another under legal requirements; 'voluntary' means the requirement is a recommendation only, not legal binding. Distinguishing whether a BES is mandatory or voluntary sometimes may be difficult since a voluntary standard may be referred to by a mandatory code and some BES only have part of the document legislated as mandatory.

arket effect' which is found useful in appliance standard (such as refrigerators and air-conditioners) cannot be easily applied to buildings (Milhone, 1992; Stern, *et al.*, 1987). Statutory requirements will help level the playing field for developers and builders as reputable designers and building professionals will not have to compete with others who achieve construction cost savings by eliminating or ignoring energy conservation features. It is the government responsibility to make sure the efficient, not the easy path is being followed.

The carrot and the stick

Supporters of voluntary approach believe that mandatory standards are the tick' limiting design freedom and innovations if the BES is not comprehensive and flexible enough. Elms (1988) pointed out that we are living in a society which is heavily regulated at all levels and in all directions, certainly additional regulations with regard to energy conservation are not required. Setting appropriate standards is difficult since what may be desirable in one building may be inappropriate in another and various buildings show widely different energy use patterns which are difficult to explain and analyse. Mandatory codes, voluntary codes, and a mixture of both are now found in different parts of the world (Janda and Busch, 1994). No matter what approach is used, a crucial factor is the acceptance of the policy as a whole by the target groups. An effective mechanism is needed for designing and implementing BES so that the benefits of energy savings (the arrot') can be realised at each level. Study of the various approaches in the world can provide a better perspective on how to select, develop and implement an effective BES.

3.2 Development of Building Energy Standards

This section provides an overview of the major BES in the world including: (a) United States and Canada, (b) some fast developing countries in Asia, (c) UK, New Zealand and Australia, and (d) other European countries and new developing countries.

3.2.1 United States and Canada

Even the briefest review will suggest that USA has now possessed the most detailed BES in the world (EMSD, 1994). The past history tells us that the U.S. federal acts and the consensus ASHRAE Standards strongly influence the federal BES and the standards enacted in different states of USA.

Federal acts and efforts

The U.S. government plays an active role in BES promotion and development. Major U.S. federal laws affecting BES include:

- *1975 Energy Policy and Conservation Act (EPCA)*, Public Law 94-163.
- *1976 Energy Conservation and Production Act (ECPA)*, Public Law 94-385.
- *1992 Energy Policy Act (EPAct)*, Public Law 102-486.

The 1975 EPCA provided exchange of information for international energy program (EIA, 1994b, pp. 95) and directed states to adopt an energy standard. The 1976 ECPA marked the initial involvement of the U.S. federal government in developing mandatory building energy performance standards. BES proposals (known as ‘10 CFR Part 435’) were prepared by the U.S. Department of Energy (USDOE) – the prime U.S. agency for promoting standard-related activities. Important proposals made so far include:

- Building energy performance standards (BEPS) for new buildings (USDOE, 1979).
- Proposed standards for new commercial and multi-family high rise residential buildings, non-federal (USDOE, 1987).

- Proposed standards for new commercial and multi-family high rise residential buildings, federal (USDOE, 1989b).

- Proposed standards for non-federal residential buildings (USDOE, 1992).

The 1979 BEPS proposal (mentioned in Section 2.4.4) is an innovative yet controversial attempt (Fleming and Misuriello, 1980). Comments received on this draft standard led USDOE to the decision to put their support behind further development of the more widely accepted ASHRAE Standards. The 1992 EPAct, signed by President Bush in October 1992, is the most important U.S. Act on BES in the 1990 (U.S. Government, 1992). Under the EPAct, every state is required to certify before October 1994 that its commercial BES provisions meet or exceed the requirements of ASHRAE 90.1-1989 (ASHRAE, 1989c). Geller, Nadel and Hopkins (1992) have estimated that the EPAct will result in 20% energy savings in 50% of new commercial buildings constructed during 1995-2010. With funding from USDOE, a number of U.S. national laboratories, such as LBL, PNL and ORNL, have conducted many research projects to support the BES development (PNL, 1983) [*]. An office called uilding Energy Standards Program' has been set up at PNL to provide basic research and assistance in the development and implementation of BES in USA. Many research studies have been conducted on commercial buildings, such as PNL (1983), Hadley and Halverson (1993) and Callaway, Thurman and Shankle (1991); the available resources on BES in the USA were also listed by Johnson (1993).

ASHRAE Standards 90 and 100 series

The ASHRAE Standards 90 series is by far the most widely adopted standard model in the world [†]. The first edition was published in August 1975 after the first oil crisis (ASHRAE, 1975a); later revised in 1980 to contain

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[*] LBL is the Lawrence Berkeley Laboratory at University of California, Bekerley; PNL is the Pacific Northwest Laboratory at Battelle; ORNL is the Oak Ridge National Laboratory at Tennessee.

[†] The ASHRAE Standard 90 series and 100 series has been approved by the Illuminating Engineering Society of North America (IESNA). ASHRAE 90A-1980, 100.2-1991, 100.6-1991 and 105-1984 (RA 90) were also approved by the American National Standards Institute (ANSI).

three parts, i.e. 90A-1980, 90B-1975 and 90C-1977 (ASHRAE, 1980). The energy and economic impacts of ASHRAE 90-1975 have been analysed by Lentz (1976a, b & c). In 1983, USDOE funded ASHRAE to form a Special Project, called P 41' (Jones, 1983), which provided direction and technical review to upgrade Standard 90A-1980 to a new Standard 90.1 (ASHRAE, 1985a, b, c & d; ASHRAE, 1984a, b & c, McDonald, 1984; Cox, 1984; Crawley and Briggs, 1988). A draft ASHRAE Standard 90.1P was published in 1985 to invite comments. Using this draft as a reference, USDOE has prepared the BES proposals in 1987 (USDOE, 1987) and 1989 (USDOE, 1989b).

The well-known ASHRAE Standard 90.1-1989 designed for commercial buildings was published in December 1989 (Wutka, *et al.*, 1990); another similar document, SHRAE 90.2-1993', has also been produced for low-rise residential buildings. To facilitate easy adoption by each state, a code language version of ASHRAE 90.1-1989 was prepared in 1993 (ASHRAE, 1994; Conover, 1993). Other aids to the use of this standard include a *User Manual* (ASHRAE, 1992b), some promotion brochure and video. The basic structure of ASHRAE 90.1-1989 is shown in Figure 3.1.

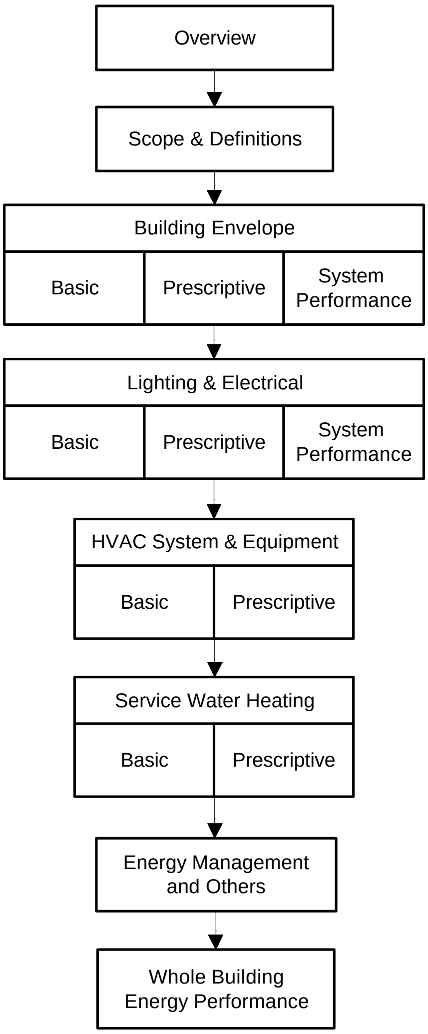

Figure 3.1 *Basic Structure of ASHRAE Standard 90.1-1989*

ASHRAE has published the ASHRAE Standard 100 series as tandard practice' for all common types of existing buildings including residential, commercial, industrial, institutional and public assembly (ASHRAE, 1981a, b, c, d, e, f & 1991a, b). A new ASHRAE Standard 100-1995 was recently proposed to combine all these different standards into one single document (ASHRAE, 1995). Another ASHRAE Standard 105-1980 (RA 90) deals with standard methods of measuring and expressing building energy performance so as to provide a consistent method for energy data (ASHRAE, 1990a).

Energy standards in different states of USA

Besides the federal and ASHRAE energy standards, the BES in different states of USA are also worth mentioning since some of them are progressive and more advanced than the national codes. A directory published by the National Conference of States on Building Codes and Standards (NCSBCS) has outlined the technical and administrative requirements of the state-wide BES (NCSBCS, 1991). The BES documents for 25 states have been obtained from the relevant state energy offices and studied in this research *. It is found that a wide range of different approaches are used in these states, ranging from simple thermal insulation requirements to advanced simulation-based building energy performance standards. A majority of them considers three major model codes as reference:

- *ASHRAE Standard 90 (either 90.1-1989, 90.1P, 90A-1980 or 90-1975)* – Different versions of the ASHRAE Standard 90 are used in different states depending on their speed of updating.

- *BOCA National Energy Conservation Code* (BOCA, 1993) – It is developed by the Building Officials and Code Administrators International, Inc.

- *CABO Model Energy Code (MEC)* (CABO, 1993 & 1986) † – It is prepared by the Council of American Building Officials (CABO) based on ASHRAE Standard 90A-1980 but with different design of format and approach.

ASHRAE Standard 90 and BOCA Code are most popular for commercial BES while MEC is more often used for residential BES (MEC 1992 edition was specified in the 1992 EPAct as the minimum provisions for residential BES). Some states have paid much efforts in

* The author has made inquiry to all 52 states in USA, but only 25 states have replied and sent their current BES's for this research study.

† The CABO Model Energy Code (MEC) was developed jointly by Building Officials & Code Administrators International, Inc. (BOCA), International Conference of Building Officials (ICBO), Southern Building Code Congress International, Inc. (SBCCI) and National Conference of States on Building Codes and Standards (NCSBCS). The Council of American Building Officials (CABO) is a federation of the first three organisation.

developing their own climate-specific BES. For example, California (CEC, 1992a), Florida (State of Florida, 1993), Oregon (Perry, Clark and Baker, 1993) and Hawaii (Eley Associates, 1993) have developed advanced standards using computer-based methods. California, in particular, is regarded as the leading one in the world. Her building energy standard, known as alifornia Title 24', is now in the third generation and it often forms an important reference for advanced BES development, including the ASHRAE Standard 90 series. The *Non-residential Manual* (CEC, 1992b) and *Alternative Calculation Method (ACM) Approval Manuals* (CEC, 1992c & d) prepared by the California Energy Commission (CEC) are considered more advanced than ASHRAE 90.1-1989 in some areas. Figure 3.2 shows the development of the ASHRAE and California standards, and their relationship with the BES in some Asian countries (see Section 3.2.2).

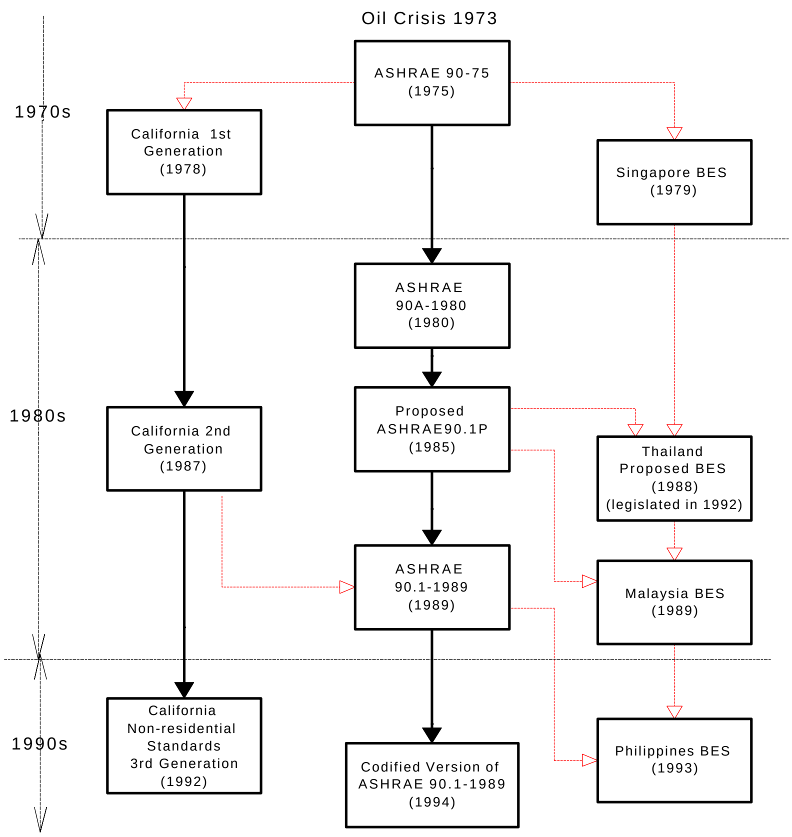

Figure 3.2 *Development of California, ASHRAE and ASEAN Standards*

Canada

Basically, Canada follows closely the U.S. approach. The ASHRAE Standard 90.1-1989 has been specified as acceptable good engineering practice in Vancouver and Ontario since August 1991 and July 1993, respectively (O alley, 1994). Building energy conservation requirements are stipulated in provincial and territorial governments of Canada in different formats. At the national level, Canada has first published a standard-related document in 1983, called *Measures for Energy Conservation in New Buildings* (NRCC, 1983). But this document is pretty vague and qualitative in nature.

In the early 1990 , the Canadian Commission on Building and Fire Code (CCBFC) was commissioned to prepare a more comprehensive energy code. Draft National Energy Codes for Houses and Buildings (CCBFC, 1994a & b) have been produced and they are now open for public review and comment. These codes are expected to be finalised and put into operation in 1996. The method proposed in the draft document is similar to the ASHRAE 90.1-1989 and some enhancements have been introduced to suit the conditions in Canada. Trade-off compliance methods have been designed for buildings (commercial) and houses (residential) so as to allow more flexibility in compliance (Sander and Cornick, 1994; Swinton and Sander, 1994).

3.2.2 Asian countries

In the past two decades, Asian countries have paid more attentions to BES as their energy demand and building development are growing very fast with the economy and population expansions. Among them, countries of ASEAN is the most progressive in Asia during the past 15 years *. BES development in ASEAN and four other Asian countries, including China (People Republic of China), Japan, South Korea and Taiwan has been studied since these countries have fast economic growth and similar social structure and weather to Hong Kong.

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* ASEAN is the Association of Southeast Asian Nations, which includes six member countries: Brunei, Indonesia, Malaysia, Philippines, Singapore and Thailand. (Vietnam is the seventh member recently admitted to ASEAN in July 1995)

ASEAN countries

The building energy conservation programmes in four major ASEAN countries (Malaysia, Philippines, Singapore and Thailand) have been reviewed by Hui and Lam (1991b). Singapore was the first nation among them to develop her BES and implement it mandatorily in 1979 for commercial buildings through the *Building Control (Space, Light and Ventilation) Regulations* (BCD, 1979b). The other ASEAN countries (except Brunei) started their research works in the 1980 using Singapore standards as a reference model. Indonesia (Janda and Busch, 1993, pp. C-46 to C-49), Malaysia (METP, 1989; Kannan, 1989 & 1987; Deringer, *et al.*, 1987), Philippines (Department of Energy, 1993) and Thailand (DEDP, 1994; Chirarattananon, 1991 & 1992; Chirarattananon and Limmeechokchai, 1994; Chirarattananon, Rakwamsuk and Kaewkiew, 1989) have already developed guidelines for energy conserving design in commercial buildings (some of them have recommended parts or the whole of the documents as a statutory requirement after public review).

When preparing her BES, Singapore has adapted the requirements of ASHRAE Standards 90-75 and 90-80A (ASHRAE, 1975a & 1980) to suit her climatic conditions and construction practices (Lim, 1994; Lim and Rao, 1979). The verall Thermal Transfer Value' (OTTV) method, which originated from ASHRAE, was expanded for the control of building envelope design (Hui and Lam, 1991a; Lam, Hui and Chan, 1993b). A handbook was published in December 1979 (later revised in 1982) to assist practitioners in meeting the design requirements (BCD, 1979a; DBCD, 1983). A set of code of practice (Singapore Standard CP24) has also been prepared to augment the regulations (SISIR, 1983, 1982a & b).

When the other ASEAN countries (Indonesia, Malaysia, Philippines, and Thailand) developed their ounger' BES in the late 1980 , they not only learnt from the Singapore experience but also made reference to the new generation of ASHRAE Standards 90 series, including the draft 90.1P and the completed 90.1-1989 (see also Figure 3.2). All of them adopted the basic OTTV concept on building envelope, but their OTTV methods have been refined to reflect their local conditions and simplify compliance (Deringer and Busch, 1992, Chp. 8); provisions for lighting, HVAC systems and electric power were similar in nature as they all followed the principles of ASHRAE Standard 90.

ASEAN-USAID Building Energy Conservation Project

An important supporting source for BES development of ASEAN is the SEAN-USAID Building Energy Conservation Project' (Deringer and Busch, 1992) [*]. The first and second phases of the project began in 1982 and 1985, respectively (Levine, 1988). It has been identified that energy saving potentials in commercial buildings throughout ASEAN is significant (Levine, Busch and Deringer, 1989) and the proposed BES can help realise these benefits. Important efforts provided by this project include:

- Transfer of the DOE-2 program (LBL, 1981) to ASEAN.
- Training for ASEAN participants on the DOE-2 program, energy analysis methods and energy auditing techniques.
- Funding to support some 22 related research projects throughout ASEAN (Levine, 1988).
- Research works and analyses conducted by the Lawrence Berkeley Laboratory (LBL) in association with the local co-ordinators in ASEAN.
- U.S. consultants working with ASEAN government officials and private sector participants to design programmes and energy conservation policies.

The results of this project are summarised in a three-volume report (Deringer and Busch, 1992; Busch, 1992; Loewen, 1992) with energy standards, technology and audit as the main themes. Within the ASEAN-USAID project,

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[*] The 'ASEAN-USAID Building Energy Conservation Project' is one of the three energy-related sub-projects sponsored by the United States Agency for International Development (USAID) as a result of the Fourth ASEAN-US Dialgoue on Development Cooperation in March 1982 (Deringer and Busch, 1992). All ASEAN countries except Brunei have participated in this eight-year project.

a key policy focus is the application of technical tools to BES development and assessment. Research efforts and training in building energy simulation, energy auditing, data collection and evaluation (for weather and energy data) are highly stressed. The databases, analyses and skills developed from the research activity form the basis and rationale of the BES recommendations in ASEAN. Deringer and Levine (1990) found that the analyses from ASEAN can be developed into a systematic tool kit for countries planning to develop their first energy standards. This methodology has been applied to some countries in Central America, such as Jamaica (Jamaica Bureau of Standards, 1992) and Ivory Coast (Janda and Busch, 1993, pp. C-54 to C57).

With the aim to upgrade her BES, Singapore has conducted several studies under the support of the ASEAN-USAID project to improve her original 1979 OTTV equation and method. Another building energy simulation program, BUNYIP (Moller and Wooldrige, 1985), was also acquired from Australia in 1986 through the ASEAN-Australia Economic Co-operation Programme (AAECP) to support the research exercise (Chou, Wong and Lee, 1990). A few suggestions for revising the 1979 Singapore OTTV equation have been made (Deringer and Busch, 1992, Chp. 8; Chou and Lee, 1988; Chou and Wong, 1986 & 1993; Chou and Chang, 1993; Turiel, Curtis and Levine, 1985) but they have not yet been adopted.

China (People Republic of China)

China system of energy supply and consumption is unique: subsidised energy enterprises, low energy prices, large energy consumption by heavy industries and stresses on energy-efficiency to meet economic goals (Levine, Liu and Sinton, 1992). When compared with the industrial and residential sectors, energy conservation in commercial buildings is not an urgent item as such on the agenda of China energy efficiency plans (Liu, Davis and Levine, 1992). BES for residential buildings have been drafted in 1986 with major focus on space heating and thermal insulation (Lang and Huang, 1993; Wirtshafter, 1988). In response to the rapid growth of hotel buildings in China, a new energy standard for tourist hotels was published in

1993 and implemented mandatorily in July 1994 (National Technology Supervision Bureau and Ministry of Construction, 1993). This hotel energy standard, being the first commercial BES in China, is prescriptive in nature and focuses on air-conditioning systems commonly found in hotel buildings. It has made reference to energy standards in USA, UK, Japan as well as the design experience of hotel buildings in some major cities in China.

Japan

The Ministry of Construction of Japan has published a BES document for commercial buildings (Ministry of International Trade and Industry, 1993) and another one for residential houses (Iwamoto, 1992). The commercial BES was first published in February 1980 to include only buildings for office use (sections one and two only in the first edition). It was later revised and expanded in 1985 to include buildings for shops and in 1991 to include hotels and inns too. The latest edition (July 1993) of the commercial standards include six sections (these titles are translated from Japanese by the author):

1. Prevention of heat loss through exterior walls, windows, etc.
2. Efficient energy utilisation of air-conditioning equipment.
3. Efficient energy utilisation of mechanical ventilation equipment (other than air-conditioning equipment).
4. Efficient energy utilisation of lighting equipment.
5. Efficient energy utilisation of hot water services equipment.
6. Efficient energy utilisation of elevators.

The heat loss requirement in section one, which aims at reducing heating load, is that: the nnual heat load’ or erimeter annual load’ (PAL) calculated per unit floor area for the perimeter zone five metres from exterior walls shall be less than the value obtained through multiplying 80 by a scale-adjustment coefficient given in a table (this coefficient takes into account the average per-floor floor area). The annual heat load and scale-adjustment coefficient are defined in the standard.

Section two focuses on cooling energy for air-conditioning purpose. The value obtained by dividing the calorific equivalence of the amount of energy consumed in a year (can be in the form of electricity, oil or gas) to handle the air-conditioning load by the ssumed’ air-conditioning load for the building shall be less than an nergy utilisation index’ of its building type. The air-conditioning load and the ssumed’ air-conditioning load are defined in the standard; the ssumed’ one is calculated without consideration of load reduction by waste-heat collection. The requirements for mechanical ventilation, lighting, hot water services and elevators in sections three to six are based on calculation of an stimated energy consumption level’. Compliance to the standard requires meeting the criteria in all the sections. On the whole, the Japanese BES (1993 edition) has considered many important energy end-uses in a commercial building and has developed simplified udget’ approach for each component.

South Korea

South Korea has implemented mandatory BES (the Korea Building Energy Performance Standards) in June 1992 using ASHRAE 90.1 and the Japanese BES as reference (Janda and Busch, 1993, pp. C-118 to C-121). The concept of nergy budget level’ (EBL) is used to limit the annual energy consumption arising from the heating and cooling load in the building (Korea Institute of Energy Research, 1994) [*]. Because of the cold climate in winter, prescriptive thermal insulation requirements are specified and emphasized for different building components in the standard.

Taiwan (under drafting)

Taiwan is now considering the implementation of BES. Some research works have been carried out to study the appropriate strategies on building

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[*] The author would like to thank Mr. Sang Won Ahn of the Department of Physics & Materials Sciences, CityU for translating the Korean document.

energy conservation (Yang and Hwang, 1993). It has been indicated that Taiwan was preparing a draft for the proposed BES by evaluating the OTTV concept of ASEAN and the perimeter annual load (PAL) concept of Japan. The index proposed by Taiwan for building envelope is called NVLOAD' which is calculated on an energy consumption basis. Draft document for the proposed BES is expected to come up soon.

3.2.3 United Kingdom, New Zealand and Australia

The BES of United Kingdom, New Zealand and Australia are interesting since they have attempted the nergy target' approach and have established some energy consumption levels based on building surveys.

United Kingdom

Thermal insulation requirements in Part L and Part F of the Building Regulations in UK can be considered as the initial form of BES (Bunn, 1994). When CIBSE started developing her BES in the 1970 , the ASHRAE (Standard 90-1975) and North America approaches have been studied. The energy target approach was selected because it could provide greater freedom to building designers (Peach, 1976; CIBS, 1982) and was the best means of effecting energy reductions (Owens, 1975). Although the arget' principle was flexible, the target figures were speculative and would be subject to debate. Cornell and Scanlon (1975) believed that a ensible' value of the target, drawn from analysis of some existing energy consumption data, had to be used initially and it should be refined as experience was gained.

The CIBSE approach consider two types of energy targets: one for design of new buildings and another for operation of existing buildings (Peach, 1976). The well-known *CIBSE Building Energy Code* has four parts: Parts 1 and 2 focus on building design (CIBSE, 1977; CIBS, 1981) whereas Parts 3 and 4 on building operation (CIBSE, 1979; CIBS, 1982). A British Standards (BS8702: 1985) with an energy design guide (BSI, 1985a & b) was published in 1985; it referred to the CIBSE code as its general approach and added some more information and a check list for easy reference in the building design process. The existing CIBSE code only addresses heated and naturally ventilated buildings in its Part 2, Section (a) (CIBS, 1981). There are proposals to expand the CIBSE code to cater for the needs of air-conditioned buildings and the draft BES proposal is now under discussions (CIBSE, 1990).

New Zealand

A historical review of building energy efficiency in New Zealand is given by Isaacs (1993) and the current development was discussed by Baird and Isaacs (1993). Like most other countries, initial efforts in New Zealand focused mainly on the insulation of residential buildings. When New Zealand developed her BES for commercial buildings in the early 1980 , both the American codes and the CIBSE code have been evaluated (Trethowen, 1982). The British CIBSE code was finally chosen as the model and the target approach was adopted with modifications for local conditions. Two types of energy performance targets were defined in New Zealand (SANZ, 1982):

- *Energy design targets* -- To be used by building designers, they specify the maximum demand which various energy consuming systems within a building could make under closely prescribed sets of conditions.

- *Energy consumption targets* -- To be used by building managers, they specify the maximum consumption of energy for a building under normal operating conditions.

The first BES of New Zealand was published in 1982 as a voluntary guideline (SANZ, 1982) directed towards both building designers and managers. Energy use data were initially developed from a one-year survey of existing buildings (Baird and Isaacs, 1993). The overall consumption targets were set for eleven commercial activities: those for existing buildings approximated the average values found in the survey and those for new buildings being set at half these values.

After ten years time, New Zealand has undergone a major revision to shift to a fully performance-based energy standard under the New Zealand Building Regulations 1992 (Baird and Isaacs, 1993). Energy efficiency provision is contained in the Building Regulation with its objective and functional requirement defined. The performance needed to meet these criteria is determined by nergy performance targets' (EPT) set by the ase energy use indices'. A manual worksheet version and a personal computer version (Isaac, *et al.*, 1993) of the procedure have been developed to simplify the compliance. More research works are needed to determine appropriate performance criteria and to evaluate energy prediction methods to be used for setting energy targets.

Australia

Australia does not yet have BES (Thomas and Prasad, 1995) but some interesting energy guidelines have been produced by the building managers: the BOMA Energy Guidelines 1994 & 1986 (BOMA, 1994 & 1986). These guidelines adopt the energy target approach (Brown, Dobney and Fricker, 1987) similar to CIBSE and New Zealand. Recommendations were given on energy management, design and operation of buildings. With the building operation experience and energy consumption data from the members of Building Owners and Managers Association (BOMA) in Australia, they were able to set out reasonable figures for the energy targets at various locations in Australia. As for energy audit process, Australia has some technical standards developed, such as Australia Standards AS 3598-1990 and AS 2725-1984 (Standard Association of Australia, 1990 & 1984). Another useful source for building energy efficiency is the *Building Energy Manual* (NSW Public Works, 1993) written by engineers, architects and researchers. This manual provides information about how to conduct evaluations and achieve energy efficiency and cost-effectiveness in building design.

Walsh (1993) has explained the national initiatives of Australia in energy efficiency and indicated that efforts have been carried out to promote this in buildings through BES development. A proposal has been made in

Victoria and studies have been conducted to assess the national stringency, code structure and likely impact of a commercial BES (SRC Australia Pty. Ltd., 1993a, b, c). Draft code from the proposal is expected to come up soon for public comments and discussions. The code will include the America technology (such as DOE-2 program) as well as the energy target method from CIBSE, New Zealand and BOMA.

3.2.4 Information on other countries

Published information about BES in other countries is very limited. Even the very basic information, such as whether or not the country has some form of BES, is difficult to determine. The reason for this is a lack of an international body to collect and maintain the information in a systematic way. The survey by Janda and Busch (1993 & 1994) is by far the best available napshot' of the international BES status. To provide more information about the BES scenario in the world, an attempt has been made in this research to study the BES in countries other than the mainstream ones. An encouraging finding is that more and more countries are now working hard to prepare or upgrade their BES . It is expected that the information provided here will be augmented by the addition of new BES and upgrades of existing ones.

Europe

The information available for Europe often does not describe to which building types the policies apply although it can be inferred from the structure that most of them concentrate on residential houses. Goulder, Lewis and Steemers (1992) have listed some useful publications and BES documents in countries of the European Communities. Major BES in Europe can be divided according to the following regions:

- *Eastern Europe* – Countries in Eastern Europe include Bulgaria, Czech and Slovak Federal Republic, Hungary, Lithuania, Poland, Romania, Ukraine Republic and Russia. Except some prescriptive thermal insulation requirements, no formal standards exist for the construction of buildings with regards to energy efficiency aspects (Lengyel, 1992). For example, the Poland standards (Polish Committee for Standardization, 1994) focuses on thermal protection of buildings with respect to heat losses and the Russia (formerly U.S.S.R.) *Building Code on Heat Engineering* is designed for heating reduction and insulation for cold climate (Drozdov, Matrosov and Tabunschikov, 1989; Matrosov and Butovsky, 1990).

- *Western Europe* – This include countries like Austria, Belgium, France, Germany, Netherlands, Spain and Switzerland. Among these countries, Austraia, France and Germany have longer history on building thermal standards (Givoni, 1976, Chp. 16). Their methods are adopted by the other countries as a reference model. France has developed since the 1960 the criteria for the performance of a whole building rather than specifying materials for its parts (Janda and Busch, 1994). A set of French thermal standards was first established in 1974 for residential buildings and in 1976 for non-residential ones (Bourdeau, 1992). The non-residential standards, updated in 1988, is mandatory and focus on thermal insulation and air-conditioning of buildings in different climatic zones of France (Bourdeau, 1992; Janda and Busch, 1993, pp. C-38 to C-41). Germany also has thermal standards and design guidelines for buildings; national standards on air-conditioning requirements (DIN, 1983) and thermal calculation procedures (DIN 4701 and VDI 2078) have been developed to specify standard methods and conditions in energy and load calculations.

- *Southern Europe* – This include countries like Greece, Italy, Portugal and Spain. Spain is a typical European country with warm climate and she has developed the *NBE-CT-79 Spanish Thermal Requirements for Buildings* (NBE, 1979) (in Spanish). The standards provides information and data about weather conditions and thermal calculation method in Spain. A maximum thermal transmission ’ factor similar to the OTTV concept was used to specify building envelope performance (NBE, 1979, pp. 71-77). The Spanish standard has been referred to by other European countries as well as some countries in South America (for historical reasons), like Argentina (Evans, 1993). Portugal has used the Spanish and the French standards as a reference for developing her mandatory BES in 1991.

- *Scandinavia* (Northern Europe) – This include four countries: Denmark, Finland, Norway and Sweden. Because of the cold climate in these countries, their building standards mainly concentrate on the limitation of heat loss. Air-conditioning requirements is comparatively less important. For example, overket' in Sweden has prepared a section within the Building Regulations to specify on limitation of heat loss under the Planning and Building Act (Boverket, 1993).

South Africa, Middle East and South America

South Africa is the only country in Africa that has indicated she has done some research works on BES. A *Manual for Energy Auditing of Building* was prepared in 1988 (Department of Public Works and Land Affairs, 1988) for promoting energy efficiency through energy auditing. Some energy surveys have been conducted in the 1980 and a research project is under way to address BES for non-domestic buildings (Rossouw, 1994).

Only a few countries in the Middle East has indicated that they have some forms of BES for promoting building energy conservation. For example, Israel has some thermal insulation standards for schools and residential buildings (SII, 1994 & 1993). Kuwait (before the Gulf War) has developed a code of practice for energy conservation in buildings using the America technology and the DOE-2 program (Kellow, 1989). In South America, Chile and Colombia has indicated that they have or are proposing BES. Brazil is also actively developing research works to support her first BES development (Lamberts, 1994). It appears that Hong Kong is only one of the many who urge BES development in the 1990 .

3.3 Implications for Hong Kong

The BES development in Hong Kong is outlined; the OTTV method for controlling building envelope design is described; the new OTTV standard in Hong Kong is evaluated.

3.3.1 Development in Hong Kong

Thermal legislation for the control of energy-efficient building design has been suggested in Hong Kong more than a decade ago (Shillinglaw, 1981; Wong, 1981) but no clear government policy has been determined. Only some general pamphlets were produced by the government, such as Building Services Branch (1995 & 1987) and Architectural Office (1983). The *aissez-faire'* (non-interventionist) government policy in Hong Kong, which dictates non-interference with the commerce and business sectors, is one of the counter argument to this legislation in the past (Lee, 1987).

Hong Kong approach

In 1980, a Joint Steering Committee on Energy Conservation in Buildings was set up by the government, architects and engineers to consider ways to conserve energy (Joint Steering Committee, 1981). After a trial study carried out by the CIBSE Hong Kong Branch (Shillinglaw and Chen, 1987; Roper, 1991), the committee recommended the OTTV concept to the government, but it was not accepted at that time. In 1991, the government set up an Energy Efficiency Advisory Committee (EEAC) to advise on how best the government could maximise energy efficiency (EEAC, 1991); an advisory note (EEAC, 1992), some brochures and TV commercials were produced by EEAC. In October 1990, a feasibility study was commissioned on the possibility of OTTV controls for air-conditioned buildings (Hui and Lam, 1991a; Lam, Hui and Chan, 1993b). A final report was completed in August 1991 (JRP, 1991) and a draft OTTV handbook was produced out of it in September 1992 suggesting the control of building envelope design in new commercial buildings and hotels (Building Authority Hong Kong, 1992). Consultation was made on the proposed K-OTTV' standard in 1992/93.

The process has taken quite a long time and the original time schedule has been extended because of lots of comments and debates.

Responses on HK-OTTV proposal

On the whole, most people support the introduction of energy standards but they also realise that more studies and analysis are needed to improve the proposal and testify the methodology, viability and stringency. The architects considered the draft OTTV code too stringent, over-restrictive and drastic in nature, and they suggested it to remain strictly for guidance purpose only (HKIA, 1992; Lau, 1992). The engineers also perceived the proposed code too stringent and could lead to considerable architectural constraint and environmental impact (Tse, *et al.*, 1993). The OTTV methodology suggested has been queried from practical point of view (Lam, Hui and Chan, 1993a & b) and recommendations have been proposed to review the OTTV limits and applications before implementing statutorily. Most people agreed that a comprehensive approach, not limited to building envelope, would be more effective and rational (Lam, Hui and Chan, 1993a; Lam, 1992b).

Hong Kong OTTV standard

After some revisions (Lam, 1995), the HK-OTTV standard was gazetted in April 1995 under a new *uilding (Energy Efficiency) Regulation'* (Hong Kong Government, 1995); the regulation has recently come into effect on 21 July 1995 under the Building Ordinance of Hong Kong (Hong Kong Government, 1991). A ode of practice' based on the draft OTTV handbook was published (Building Authority Hong Kong, 1995) and the OTTV requirements now applies to new commercial buildings and hotels in Hong Kong. New building codes for lighting, air-conditioning and lifts are being worked out now to apply to new buildings at a later time. This marks the first step of Hong Kong in her way to develop a comprehensive BES.

3.3.2 OTTV and building envelope design

The OTTV method has been adopted in many developing countries since it is relatively simple and easy to implement. Salient features and characteristics of OTTV are outlined here to help understand its basic properties and limitations.

OTTV concepts

Basically, overall thermal transfer value (OTTV) is a measure of heat transfer through the external envelope of a building and can be expressed as:

$$OTTV = \frac{Q}{A} \tag{3.1}$$

where Q = total heat transfer through the building envelope (W)

A = gross area of building envelope (m^2)

OTTV is an index of the overall thermal performance of the building envelope – the higher the OTTV value, the greater the heat gain and hence more energy will be required for cooling. Three components of heat gain are considered: (a) conduction through opaque walls, (b) conduction through window glass and (c) solar radiation through window glass. The usual practice is to have two sets of OTTV value – one for exterior walls (including windows) and the other for the roof (including skylights, if any). The approach and equations for calculating roof OTTV are similar to those for walls. Calculation for roof is often much simpler since the roof usually does not contain large amount of glazing. The general OTTV equation for wall is described in the following.

General form of OTTV equation

As walls at different orientation receive different amounts of solar radiation, the general procedure is to calculate first the OTTV of individual walls with the same orientation and construction, then the OTTV of the whole exterior wall is given by the weighted average of these values, like this (Hui and Lam, 1991c):

$$OTTV_i = \frac{Q_{wc} + Q_{gc} + Q_{sol}}{A_i}$$

$$= \frac{(A_w \times U_w \times TD_{eq}) + (A_f \times U_f \times DT) + (A_f \times SC \times SF)}{A_i} \qquad (3.2)$$

where $OTTV_i$ = overall thermal transfer value of walls with the same orientation and construction (W/m^2)

Q_{wc} = heat conduction through opaque walls (W)

Q_{gc} = heat conduction through window glass (W)

Q_{sol} = solar radiation through window glass (W)

A_w = area of opaque wall (m^2)

U_w = U-value of opaque wall (W/m^2 K)

TD_{eq} = equivalent temperature difference (K)

A_f = area of fenestration (m^2)

U_f = U-value of fenestration (W/m^2 K)

DT = temperature difference or delta temperature between exterior and interior (K)

SC = shading coefficient of fenestration (dimensionless)

= $SC_{win} \times SSF$

SC_{win} = shading coefficient of window glass (dimensionless)

SSF = solar shade factor of external shading devices (dimensionless)

SF = solar factor of fenestration (W/m^2)

A_i = gross area of the walls (m^2) = $A_w + A_f$

and, $$OTTV_{wall} = \frac{\sum_i (OTTV_i \times A_i)}{\sum_i A_i} \qquad (3.3)$$

where $OTTV_{wall}$ = OTTV of the whole exterior wall (W/m^2)

Alternatively, Equation (3.2) can be written in a compact form using the terms of window-to-wall ratio (WWR), like this (Chou and Lee, 1988):

$$OTTV_i = (1 - WWR) \times U_w \times TD_{eq} + WWR \times U_f \times DT + WWR \times SC \times SF \quad (3.4)$$

where WWR = window-to-wall ratio (gross wall area) = A_f / A_i

When applied in different countries, the general form of OTTV equation may have been modified to eliminate unimportant terms and include additional variables. For example, the glass conduction component was dropped in Malaysia (METP, 1989) and Hong Kong (Building Authority Hong Kong, 1995); solar absorptivity (♋) has been added in Malaysia, Philippines (Department of Energy, 1993) and Hong Kong; Jamaica (Jamaica Bureau of Standards, 1992) has separated the wall conduction component into two terms. The wall OTTV equation for Hong Kong, in the compact form, looks like this:

$$OTTV_i = (1 - WWR) \times a \times U_w \times TD_{eq} + WWR \times SC_{win} \times ESM \times SF \quad (3.5)$$

where ♋ = solar absorptivity of wall (dimensionless)

ESM = external shading multiplier, similar to the solar shade factor in Equation (3.2) (dimensionless)

Characteristics of OTTV

The precise characteristics and implications of OTTV depend very much on how the parameters TD_{eq},, DT and SF are derived. Hui and Lam (1991c) have showed that OTTV formulation is influenced by the selection of time period (such as summer or whole year), simulation output (such as heat gain, cooling load or chiller load) and relative importance of the components. The form of the OTTV equation will vary if different choice of variables and their ranges are taken in the analysis. Originally, OTTV was designed for indication of eat gains’ only, as in ASHRAE (1980 & 1975a) and DBCD (1983). But it was used later for relating chiller load and cooling energy (Deringer and Busch, 1992; Busch and Deringer, 1987; JRP, 1991), like this:

$$Chiller\ Load = k_1 + k_2 \times OTTV \quad (3.6)$$

where k_1 and k_2 are regression coefficients (k_1 represents the constant internal loads or ase loads’).

This extension makes the OTTV concept more useful for showing building energy performance, but, at the same time, there are complications of building operation hours and HVAC system interactions which are difficult to generalise. As OTTV only considers building envelope parameters, the relationship developed in Equation (3.6) will be confined to the particular building specification selected for the OTTV analysis. It is important to understand that OTTV is merely a measure of omparative' performance and not an indicator of the total energy that will be consumed for cooling, or how close to the optimum a particular design comes (Hui and Lam, 1991c).

3.3.3 Evaluation of Hong Kong OTTV standard

Since the Hong Kong OTTV standard has been in effect only recently (in July 1995), it is too early to say whether it is effective or not. It will take a few years for the real influences of the regulation to be felt. Nevertheless, the properties of the standard can be studied by comparing with similar methods in other countries and by analysing the basic components of the OTTV equation.

Comparison with ASEAN OTTV standards

When deriving the OTTV standard, Hong Kong has made reference to the experience in ASEAN since they have similar climates and conditions. A comparison of the OTTV standards in five ASEAN countries and in Hong Kong is given in Table 3.1. These standards have many similar features (such as OTTV limits, form of equation and parameters) as development of the younger standards are often influenced by the preceding ones and all of them have used the merican technology' to set up the basic OTTV equations (Deringer and Busch, 1992; JRP, 1991).

Table 3.1 Comparison of OTTV Standards in ASEAN and Hong Kong

	Singapore	Malaysia	Indonesia	Thailand	Philippines	Hong Kong
Latitude (North)	1° 20’ Singapore	3° 7’ Kuala Lumpur	6° 11’ Jakarta	13° 41’ Bangkok	14° 35’ Manila	22° 18’ Hong Kong
Year adopted	1979	1989	Proposed	1992	1993	1995
Current Status	Mandatory	Voluntary	Proposed	Mandatory	Voluntary	Mandatory
Applied to	new bldgs. for comm. use	new & existing bldgs. for comm. use	N/A	new & existing bldgs. for comm. use	new bldgs. for comm. use	new comm. bldgs. & hotels
OTTV limits for walls (W/m²)	45	45	45	45 (new) 55 (extg.)	48	Towe r : 35, podium: 80
OTTV limits for roof (W/m²)	45 (max. U-value if no skylights)	25 (max. U-value if no skylights)	N/A	25 (max. U-value if no skylights)	Max. U-value if no skylights	(average for walls & roof)
TD_{eq} for walls (K)	10 - 15 (depend on wt.)	19.1 ♋	10 - 15 (depend on wt./♋)	9 - 18 (depend on wt./♋)	12.65 ♋ (off.), 5.4 ♋ (hotel)	1.4 - 7.5 (depend on wt./♋)
TD_{eq} for roof (K)	16 - 24 (depend on wt.)	16 - 24 (depend on wt.)	N/A	12 - 32 (depend on wt./♋)	–	7.9 - 18.6 (depend on wt./♋)
DT for walls (K)	5	neglected	N/A	5	3.35 (off.) 1.10 (hotel)	neglected
DT for roof (K)	5	neglected	N/A	5	–	neglected
Average SF for walls (W/m²)	130	194	147	160	161 (off.) 142 (hotel) 151 (store)	160
Average SF for roof (W/m²)	320	488	N/A	370	–	264
Consider exterior shading?	Yes	Yes	N/A	Yes	No	Yes
Daylighting credits?	No	Yes (10% or 20%)	N/A	N/A	Yes (10%)	No

Notes: 1. OTTV = overall thermal transfer value; TD_{eq} = equivalent temperature difference (for walls or roof); DT = delta temperature difference (for windows); ♋ = solar absorptivity of walls; SF = solar factor

2. Average SF for walls is calculated for the four principal directions (N, E, S, W).

The OTTV standards of Singapore, Thailand and Hong Kong are mandatory while those for Malaysia and Philippines are voluntary (the one for Indonesia is a proposal). It is interesting to note that the magic number ‘45 /m^2’ is often used as the wall OTTV limit in ASEAN, although the parameters in their OTTV equations are not all the same. The OTTV limits for Hong Kong (for the weighted average of walls and roof) are 35 W/m^2 for tower and 80 W/m^2 for podium *. In the initial HK-OTTV proposal (Building Authority Hong Kong, 1992), the OTTV limits suggested are only 16 W/m^2 for commercial buildings and 30 W/m^2 for hotels.

Analysis of major components in OTTV

In order to have a clear idea of the properties of OTTV, the major components of different OTTV equations have been studied using a reference building as a base. Table 3.2 gives the key envelope parameters of the reference building (further details of the building model can be found in Section 6.3). Based on these parameters, the OTTV values and its components for six OTTV methods have been determined and compared in Table 3.3. The current OTTV limits in each country are also given for easy reference.

Table 3.2 Key Envelope Parameters of Reference Building

	Surface area (m^2)	Wall/roof weight (kg/m^2)	U-value (W/m^2 · K)		Shad. coeff. of glass	Window-to-wall ratio	Solar absorpt.
			Opaque	Glass	SC	WWR	♋
Wall	19,040	55	2.005	5.6	0.4	0.44	0.7
Roof	1,029	496	0.539	No skylights			0.7

Notes: 1. Surface area is the gross area including opaque and glass portions. Wall/roof weight refers only to the opaque portion.

2. See Section 6.3 for more information about the reference building.

* ‘Podium’ refers to the lower part of a building which is within 15 m above ground level; ‘tower’ is the part of the building above the podium (Building Authority Hong Kong, 1995). An office tower with a commercial podium (such as shopping arcades) is common in Hong Kong for large commercial buildings.

Table 3.3 Comparison of OTTV Components and Limits

OTTV method (latitude)	Wall OTTV (W/m²)	Components for wall OTTV (W/m²)			Roof OTTV (W/m²)	Envelope OTTV (W/m²)	OTTV limits (W/m²)	
		WC	GC	SOL			Wall	Roof
ASHRAE	104.8	27.8 (26.5%)	12.3 (11.8%)	64.6 (61.7%)	16	100.2	94	26.8
Singapore (1°20' N)	51.8	16.8 (32.5%)	12.3 (23.8%)	22.7 (43.7%)	32.1	50.8	45	45
Malaysia (3°7' N)	48.9	15 (30.7%)	negl.	33.9 (69.3%)	32.1	48	45	25
Thailand (13°41' N)	59.3	19.1 (32.2%)	12.3 (20.8%)	27.9 (47%)	48.1	58.7	45	25
Philippines (14°35' N)	46.5	9.9 (21.3%)	8.3 (17.7%)	28.3 (61%)	17.8	45	48	N/A
Hong Kong (22°18' N)	32.2	4.1 (12.8%)	negl.	28.1 (87.2%)	13.7	31.3	35 (tower) 80 (podium)	

Notes: 1. OTTV = overall thermal transfer value; WC = wall conduction; GC = window glass conduction; SOL = solar radiation. Envelope OTTV is the weighted average of wall and roof OTTV by their surface areas (OTTV limit for Hong Kong is based on this weighted average).

2. The above values are calculated for the reference building envelope (see Table 3.2 and Section 6.3 for detail).

It can be seen from Table 3.3 that the reference building meets the Hong Kong and Philippines limits but exceeds the Malaysia and Thailand limits. The roof limits of ASHRAE and Singapore can be met by the building, but not the wall limits. The results imply that the current OTTV criterion in Hong Kong (i.e. 35 W/m²) is oderate' as compared with other countries; the OTTV limit allowed for podium (i.e. 80 W/m²) is generous from energy point of view. Analysis of the wall OTTV components shows that solar radiation is a dominating factor which accounts for a percentage from 43.7% (Singapore) to 87.2% (Hong Kong) in the six OTTV methods studied; window glass conduction is either neglected or contributes only from 12.8% (ASHRAE) up to 23.8% (Singapore); wall conduction varies from 12.8% (Hong Kong) to 32.5% (Singapore). It is interesting that the relative importance of solar components appears to relate to the latitude: Hong Kong at 22°18' north latitude has the highest solar percentage; Singapore at 1°20' has the lowest solar percentage; Philippines and Thailand (at 13°41' and 14°35', respectively) lies between the former two. The result for Malaysia is suspicious since she has small latitude (3°7’) but high solar percentage (second next to Hong Kong). The reason is that the solar radiation data for OTTV analysis in Malaysia are not taken from local measurements but are synthesized using data from a nearby location (Deringer and Busch, 1992, Chp. 3).

Assessment of solar factors

Since the solar component is predominant in OTTV, it is worth looking closely at the solar factor (SF) in the OTTV equations. The original ASHRAE OTTV method did not provide different SF values for vertical surfaces at different orientations (ASHRAE, 1980), but the ASEAN and Hong Kong methods have such information. The average solar factors for ASEAN and Hong Kong OTTV equations can be found in Table 3.1. Direct comparison of these values may be misleading since OTTV is a relative value which varies with the analysis methods. To examine how the solar factors vary at different orientation, the SF values in different OTTV methods are plotted in Figure 3.3 (Philippines has three sets of SF values for office, store and hotel, respectively). It can be seen that the SF profiles for Malaysia and Singapore (which are the earliest OTTV standards in ASEAN) are similar – both are ’ shape with peaks at the east and west directions. SF profiles for other methods look like a mountain with crests near the south direction.

The SF profile in OTTV methods have been compared with the theoretical basis of solar calculations in ASHRAE (1993, Chp. 27). Figure 3.4 shows the profiles of olar factors’ (W/m²) for latitude from 0° to 40° north, estimated using the olar heat gain factor’ (SHGF) of ASHRAE (by summing SHGF for the whole year). By comparing Figures 3.3 and 3.4, it can be seen that the SF profiles in OTTV methods are similar to the theoretical ones: SF profiles at lower latitude have a ’ shape and they gradually change to a ountain’ shape as the latitude increases. A clear understanding of the properties of SF can provide useful hints for assessing the OTTV methods and achieving effective window design in the building.

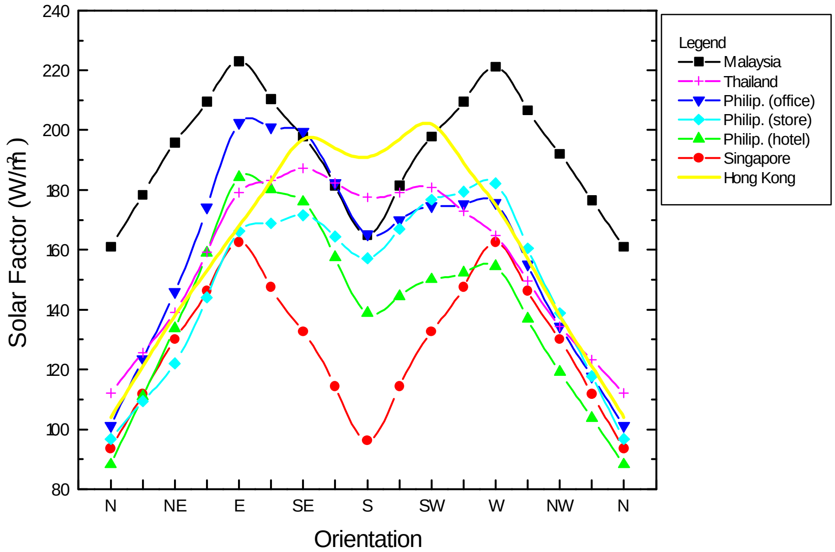

Figure 3.3 *Comparison of Solar Factors for Different OTTV Methods*

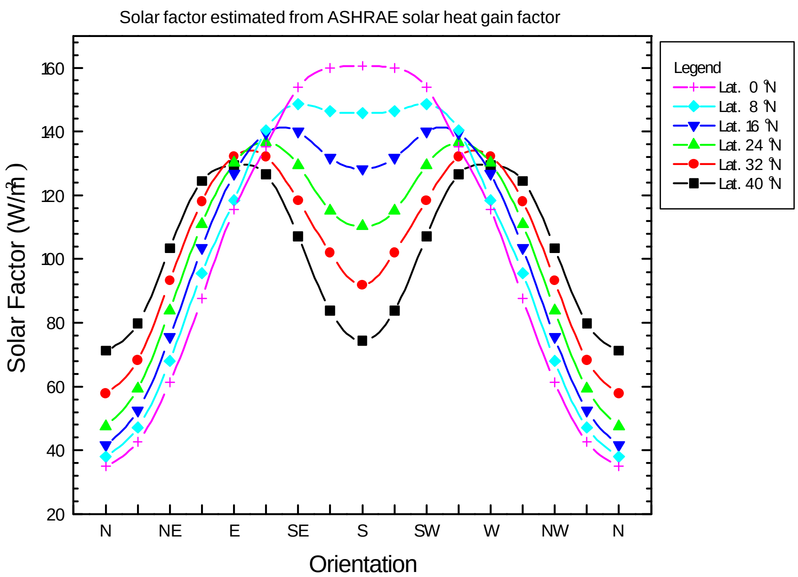

Figure 3.4 *Solar Factors Estimated from ASHRAE Solar Heat Gain Factors*

3.4 Useful Experience Learned

Important issues for BES development are analysed and outlined systematically. The development process and research works required for an effective BES are discussed.

3.4.1 Analysis of important issues

There are many technical and non-technical issues surrounding BES development which make it difficult to understand and approach. A systematic analysis of the related issues are outlined in this section. The important issues can be classified into five categories: (a) policy, (b) structural, (c) application, (d) requirement and (e) implementation. It is hoped that the information can help formulate effective strategies for BES development in Hong Kong and other locations.

Policy issues

Lim (1982) pointed out that the success of BES depended on the will of the authorities to persist with the policy, the back-up of research and testing, and the co-operation of the professions to forsake initial inconvenience. Four important areas should be considered:

- *Institutions involved for standards development* – Professional and research institutions, government agency and foreign agencies may be involved.

- *Information used for analysis* – This may include energy data of existing buildings, local climatic information and existing standards from other countries. Modern BES often requires computer simulation for energy analysis; acquiring of and being familiar with these programs are needed.

- *Relationship with building regulations* – Implementation under the existing building regulations is a common method for BES. To avoid conflicts between the efficiency goal and other building requirements, the building regulations should be evaluated and coordinated carefully (Goodsall, 1994).

- *Interactions with other standards* – It is necessary to ensure consistency between the BES requirements and the indoor environmental criteria in ventilation and thermal standards, such as ASHRAE (1989b), ASHRAE (1992a) and ISO (1984). The availability of related supporting standards, such as appliance efficiency standards for HVAC equipment, is also important.

- *Stringency level* – BES that are stringent for one country may be ineffective in another country (Janda and Busch, 1994). The stringent level should consider the performance of existing buildings and the intended goals of the overall energy policy (often a political rather than a technical decision).

Structural issues

These issues refer to how a BES is designed and structured. Generally, two important aspects should be considered:

- *Code structure and reference model(s)* – The code structure will determine how the BES should be developed and interpreted. Generally, three code models are commonly used: (a) the America models (such as ASHRAE 90.1-1989), (b) the energy target models (such as New Zealand and UK) and (c) the Asian models (such as ASEAN). For countries with warm climates, the ASHRAE Standards (the inevitable reference) have some points on air-conditioning for the warmer part of USA; BES of California, Florida, Spain and Jamaica are also useful. The Japanese code is simple and has addressed the important areas for commercial buildings. The latest energy-target approach of New Zealand may also be adapted by adjusting for local climatic conditions and construction methods.

- *Code language and readability* – BES are to be read by eople' and they should be designed in a systematic way with good readability and clear requirements. A public review process is instructive for collecting comments. An English version of the code (if it is written in other language) is useful for international comparison and for inviting comments.

Application issues

What type(s) of buildings the BES will be applied to should be considered carefully. In the past, BES for commercial and residential buildings were not segregated, but now they often form two different streams. Classification by building type is necessary since different buildings have different energy use characteristics, such as offices, hotels and shops. The more specifically a standard has described its applicability, the more effective coverage it is likely to be (Janda and Busch, 1994). But it is also essential to strike a balance between the range of application and flexibility. A wide range of choice is available for selecting model codes for controls of new buildings or retrofits, but only limited examples exist for existing buildings. Normally, new buildings and retrofits are the first target of BES and existing building structures will be included as more experience is gained, since changing all existing buildings in a short time may be too drastic. BES for existing buildings usually lag behind that for new buildings (Marshall and Petersen, 1979). Standards or guidelines for existing buildings emphasize the importance of energy audits and good housekeeping (Chan, 1994).

Requirement issues

BES usually contains some basic requirements which must be met at all time, such as selection of design conditions and calculation procedure. Then, there are different alternative paths to demonstrate compliance, such as prescriptive path, system performance path and energy cost budget (or whole building performance) method (Wutka, *et al.*, 1990). The common compliance methods of BES are shown in Figure 3.5. The most common components of building design addressed include: building envelope, HVAC systems and equipment, lighting, electric power, auxiliary systems, service water heating and energy management system. Some BES makers may initially settle for prescriptive methods in some parts or the whole of the standard, but with an ultimate aim at a performance-based approach. For maximum flexibility to suit different users, the BES may include both prescriptive and performance options as well as an alternative compliance path.

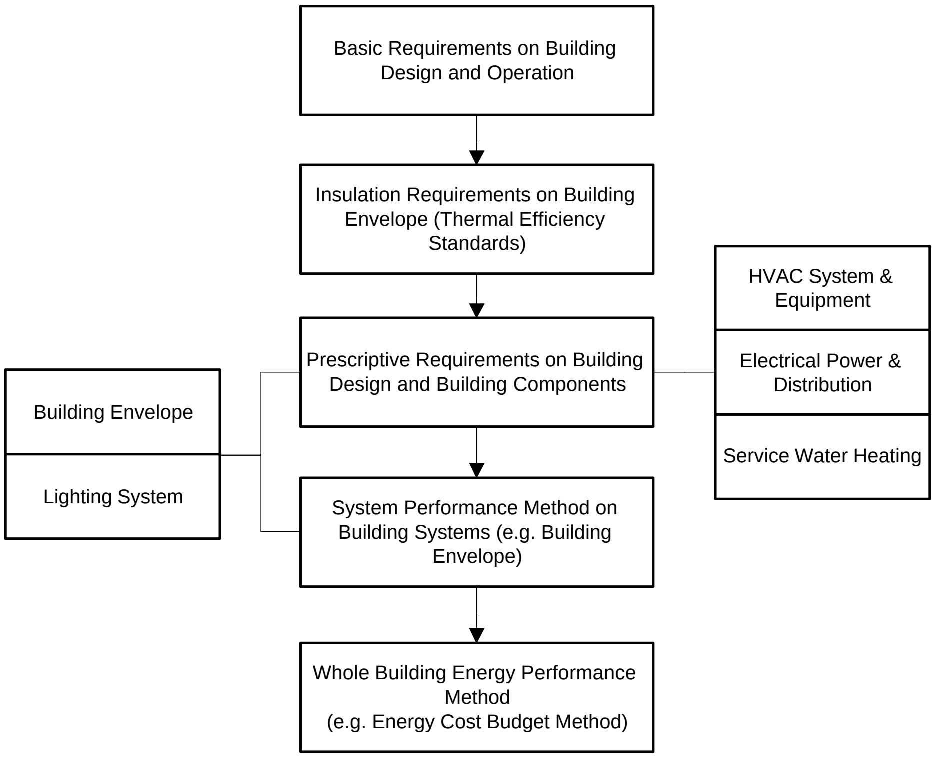

Figure 3.5 *Requirements and Compliance of Building Energy Standards*

In between detailed simulation and simple prescriptive methods, simplified computer programs can be developed to assist average building designers. Typical examples are the ENVSTD and LTGSTD programs of ASHRAE 90.1-1989 (Crawley and Boulin, 1990), the COMPLY 24 program of California standards (Gabel and Howley, 1993), the FLA / COM-94 program of Florida Code (Energy Code Program, 1993), the BRE Domestic Energy Model (BREDEM) in UK (Anderson, 1985), the Automated Compliance for Residential Energy Standards (ACRES) and the Automated Residential Energy Standard (ARES) programs of USDOE (USDOE, 1991 & 1989a). CIBSE is also testing a computer version of the calculation procedure of the proposed updates to its energy code.

Implementation issues

No matter how sophisticated a BES is designed, it will not generate any energy savings if not properly implemented and maintained. The common considerations on implementation include:

- *Phased implementation* – A ead time’ of one to three years is needed for the impact of BES to be felt. A well-planned time-table is important for good timing of basic studies, consultation, actual implementation, impact assessment and feedbacks.

- *Enforcement* – Responsible agencies, checking methodology, enforcement procedure, administrative structure and testing facilities should be considered.

- *Incentives* – Positive or negative penalties (such as rebates) are required to encourage people to think deeply about energy efficiency and to create a viable market environment for energy efficiency products.

- *Training and education* – Training for building professionals and building officials, public awareness and information campaign are important to increase acceptance and improve people commitment to the judicious use of energy. Attitude of the final users towards energy use remains an important factor in the extent of energy conservation realised.

- *Technical documents and updates*– Guidelines, handbooks, etc. explaining BES compliance and technical matters will be very useful. Continual updates of the standards will help keep abreast with the rapidly changing technologies and the industry needs (Thomas and Prasad, 1995).

3.4.2 Filling the information gap

Janda and Busch (1994) found that the lack of information about the contents of standards reflects an international information gap surrounding the development, use and effectiveness of energy standards. A systematic, co-ordinated study for BES and its related energy performance analyses is required, particularly for developing countries. Deringer and Levine (1990) have observed that only a handful of researchers in ASEAN works full-time on this subject. It is afraid that there are not much in other developing countries although a number of different professional disciplines have showed concerns. Briggs and Brambley (1991) have recognised the limitation of current whole-building performance path and the importance of developing research basis for future performance standards rather than the standards themselves. It is understandable that many developing countries do not have a well-established infrastructure and past history for energy studies. Most of them make use of the technology transferred from other advanced countries to set up their BES . It will take a certain period of operation and development before the climatic- and society-specific elements can be fully recognised and established in their codes. In-depth studies of building climatic design and factors will be useful for promoting better understandings of energy efficiency in their climate and conditions.

Establish local information

Although the principles in building energy efficiency established in more advanced countries can be referred to for developing BES, local information is required to formulate specific requirements and to justify the methods adopted. When analysing the ASEAN energy standards, Deringer and Levine (1990) have suggested two main processes for systematic BES development: (a) policy process and (b) analysis process. Figure 3.6 shows the keys steps and components of the two processes. Further details can be found in Deringer and Busch (1992). The actual procedure of BES development in a country will depend on the circumstance, but the basic requirements needed for supporting the standard will include three major aspects:

- Development and analysis of local climatic data.
- Analysis and establishment of typical buildings.
- Development of building energy simulation techniques and conducting of simulation analysis.

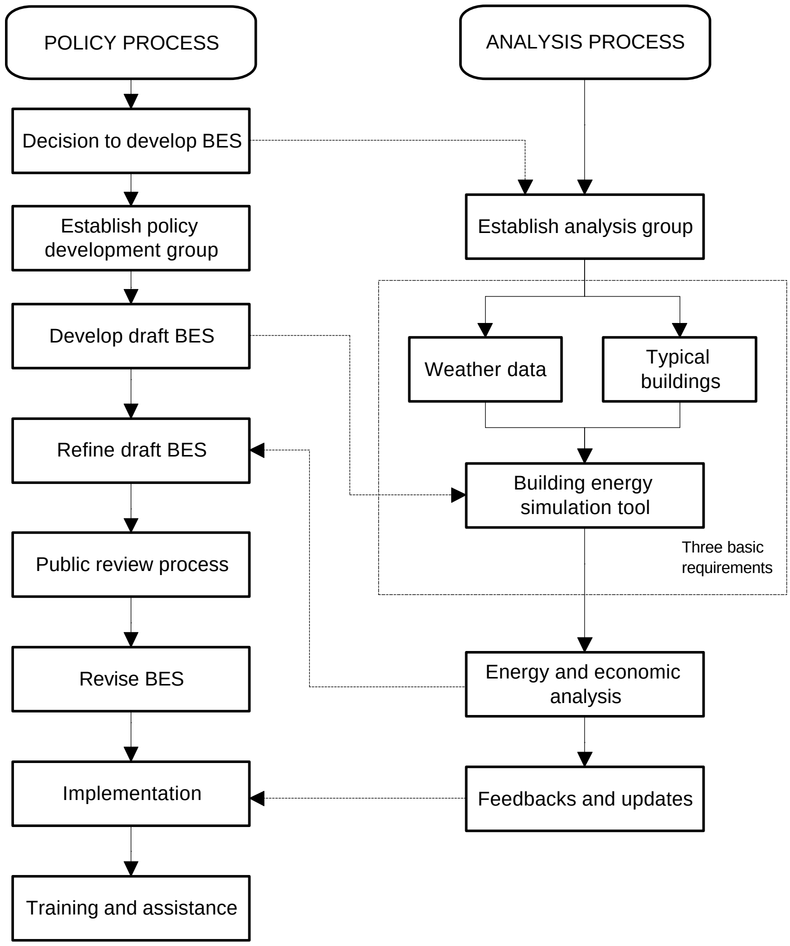

Figure 3.6 *Development Process of Building Energy Standard*

To help analyse the particular conditions in Hong Kong, the author has carefully researched and developed technical information related to these aspects. Investigations of climatic data for building design and energy analysis are provided in Chapters 4 and 5, respectively; development of simulation models for typical office buildings and analysis of building energy performance using energy simulation methods are explained in Chapter 6.