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# Development of Energy Labels for Residential Buildings in Hong Kong

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## ABSTRACT

To promote energy efficiency for residential buildings in Hong Kong, a research has been conducted to investigate the characteristics of energy consumption in the residential buildings and develop a suitable energy labelling system for assessing the building energy performance. The aims of the research are to review worldwide experience, study the feasibility of establishing building energy labels in Hong Kong, and evaluate the key factors for design and implementation of the building energy labels.

The experience in Europe, North America, Australia, Singapore and China has been studied. It is found that appliance energy labels are widely used in many countries; they are effective policy instruments to help increase awareness and overcome the market barriers. Some countries have extended them and developed energy labels for buildings. In Europe, with the launch of the European Union (EU) Directive on Energy Performance of Buildings, energy certificates and labels are being set up to grade buildings in terms of energy performance. Similar approach is being taken by USA, mainland China and other countries.

The characteristics of energy consumption of typical residential buildings in Hong Kong have been analyzed. An energy equation for assessing energy consumption of high-rise residential buildings has been established by building energy simulation method and practical design assessment. The final form of the energy equation includes six major factors, namely, HVAC coefficient of performance, window shading, lighting power density, hot water intensity, other appliance intensity and refrigerator energy.

## INTRODUCTION

Energy issue is very important to every society and energy efficiency of the residential sector is a key factor for sustainable development (Beerepoot, 2007; IEA, 2008; Santamouris, 2005; Zhang, Yan and Jiang, 2007). In Hong Kong, the residential building sector contributes about 16% of the final energy requirements and the total amount of end-use energy in the residential sector has been doubled in the past two decades (Chow, 2001; EMSD, 2008b; Lam, 1996; Tso and Yau, 2003). Fig. 1 shows the energy end-use of four different sectors in Hong Kong in 1984-2006. With growing population and fast economic and building development, it is expected that the energy consumption in the buildings will continue to increase in the coming future.

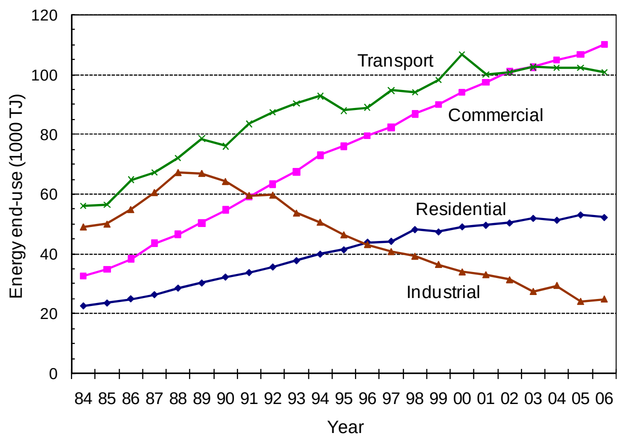


*Fig. 1. Energy end-use of different sectors in Hong Kong (1984-2006)[Data source: EMSD (2008b)]*

### Residential Buildings in Hong Kong

The residential buildings in Hong Kong are classified into four main categories, namely: private, public, subsidized sales flats (home ownership scheme) and other housing (EMSD, 2008b). The energy end-use of each of them in 2006 is shown in Fig. 2.

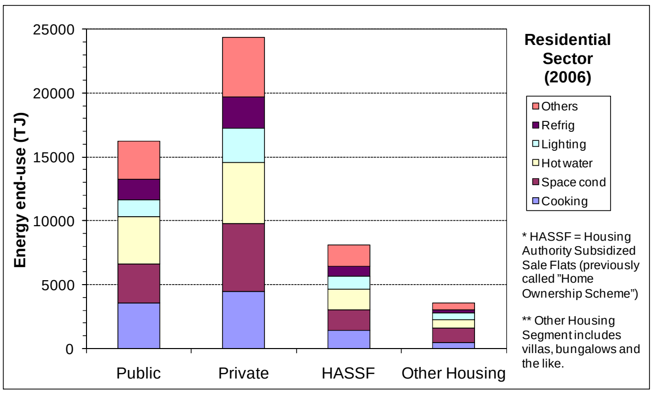


*Fig. 2. Energy end-use of the residential sector in Hong Kong (2006) [Data source: EMSD (2008b)]*

It can be seen from Fig. 2 that the private and public housings are the most important categories, contributing respectively 47% and 31% of the total residential energy consumption. The private and public housings are mainly high-rise residential building blocks with 10 to 50 storeys high and each flat in the blocks has a typical floor area ranging from 30 to 150 square metres.

## Energy Consumption Patterns

The typical energy consumption pattern of the private housing in Hong Kong is shown in Fig. 3. Similar patterns can also be found in public housing and subsidized sales flats (home ownership scheme). In terms of end-use functions, the energy consumption of residential buildings in Hong Kong can be divided into five main usages:

- Space conditioning (22%)
- Lighting and refrigerator (21%)
- Hot water (20%)
- Cooking (18%)
- Others (19%)

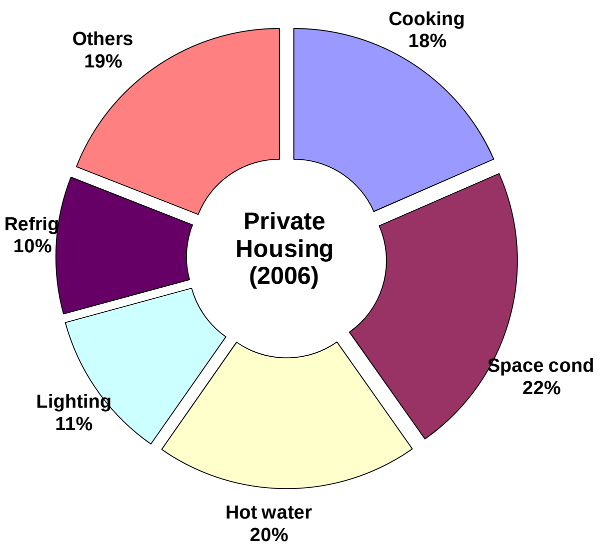


*Fig. 3. Energy end-use pattern of private housing in Hong Kong (2006)[Data source: EMSD (2008b)]*

Electricity is the major form of energy supplied to the residential buildings in Hong Kong, for running electrical appliances, lighting, and sometimes for producing hot water (e.g. using electric water heaters) and for cooking (e.g. using induction cookers and micro-wave ovens). Fuel gases including town gas and liquefied petroleum gas (LPG) are commonly used for cooking and hot water.

It is believed that the potential for energy saving in the residential buildings is large (Chow, 2001; Hui, 2001; Lam, 1996; Wan and Yik, 2004). In order to encourage energy conservation and awareness, a number of government policy tools and programmes have been implemented in the past 15 years (EMSD, 2004; Hui, 2007).

## Energy Efficiency Programmes in Hong Kong

To promote appliance energy efficiency, the Hong Kong Government has established a voluntary Energy Efficiency Labelling Scheme (EELS) for electrical appliances (including household and office equipment) since 1995 (Lam, 2001). The aim is to promote energy saving and efficiency by means of market force. At present, 18 types of household and office equipments are covered by the voluntary labelling scheme.

To enhance further the public awareness on energy consumption and global climate change, a mandatory labelling scheme for three products (i.e. air-conditioners, refrigerators and compact fluorescent lamps) was enforced in 2008 (EMSD, 2008a) through the *Energy Efficiency (Labelling of Products) Ordinance Cap. 598*. Figure 4 shows examples of the mandatory appliance energy labels.

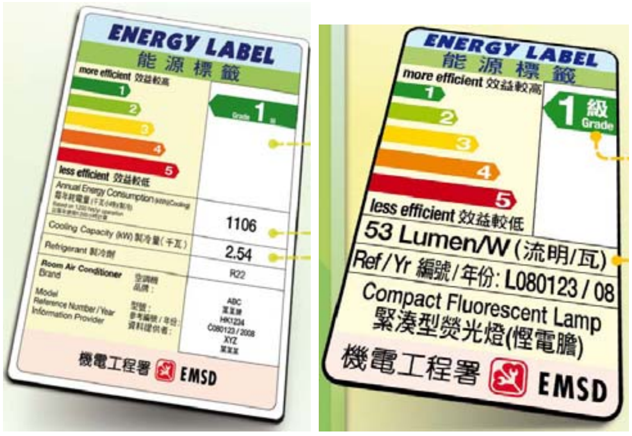


*Fig. 4. Mandatory appliance energy labels in Hong Kong*

To provide a degree of control over building design practices and to encourage awareness of energy conscious design in buildings, building energy codes (BEC) have been developed in Hong Kong since 1990s (Hui, 2007 & 2000). The current BEC in Hong Kong cover various aspects of building design including building envelope, lighting systems, air-conditioning systems, electrical systems and lift and escalator installations. A performance-based BEC was also established to allow trade-offs and provide an alternative compliance path for some complicated and innovative building projects (Hui, 2002).

The building envelope (Overall Thermal Transfer Value, OTTV) code is linked with the *Building (Energy Efficiency) Regulations*, forming a mandatory requirement for new commercial and hotel buildings. The other five BEC are implemented on a voluntary basis under the Hong Kong Energy Efficiency Registration Scheme for Buildings. It is expected that these voluntary codes will soon be combined and changed to mandatory implementation under a new *Energy Ordinance* (EB and EMSD, 2008; EMSD, 2009).

At present, many of the BEC and energy efficiency programmes in Hong Kong focus on commercial buildings. Although the appliance EELS and mandatory BEC could influence indirectly the consumer behaviour and help to achieve energy conservation in residential buildings, there is still a lack of effective measures to overcome the market barriers for energy efficiency in the residential sector. It is believed that an energy labelling system for assessing the energy performance of residential buildings could be a useful strategy.

## REVIEW OF WORLDWIDE EXPERIENCE

In many countries of the world, energy policy and regulations have been implemented to promote energy efficiency of residential and other types of buildings (Beerepoot, 2007; Cantin, *et al.*, 2007; Casals, 2006; Janda and Busch, 1994; Santamouris, 2005; Yao, Li and Steemers, 2005). Usually, there are three key policy objectives: environmental protection, improvement of competitiveness and increase of energy supply security.

To enable consumers to compare building performances from a sustainable energy point of view, a comprehensive labelling scheme is important (CLER, 2003). On the pedagogic level, such a simplified method would show essential criteria to enhance the building performance. The objective of such a label is twofold: to avoid the main errors through energy efficiency practices, and to promote better efficiency buildings through comparison and information.

### European Union

Energy labels on buildings are mandatory in Europe since 2006 with the application of the European directive 2002/91/CE on the energy performance of buildings (EU, 2003). This Energy Performance of Buildings Directive (EPBD), adopted in late 2002, forms an overall framework to promote energy efficiency of buildings in Europe. The EPBD obliges specific forms of information and advice on performance in terms of building energy certificate/label to building owner and purchasers. Energy rating of a residential building can provide specific information on the energy consumption and the relative energy efficiency of the building (Santamouris, 2005).

Besides energy performance rating (BSI, 2008), the label also provides recommendations for cost-effective improvements. This will help consumers to make informed decisions leading to practical actions to improve building energy performance and promote energy efficiency (Roulet and Anderson, 2006).

Under the EPBD, an energy performance certificate (BSI, 2007) shall be established and issued to the correspondent when buildings are constructed, sold or rented out. The energy certificate is mandatory for new and existing buildings and is determined by independent and qualified experts. The purpose of the certificate is to provide general energy status of the building including current legal standards and recommendations for future improvement.

To maintain the validity, each certificate shall be renewed not more than ten years. Casals (2006) pointed out that although the EPBD presents several shortcomings that may limit its effectiveness, the certificate itself do allow straight-forward comparison among different buildings and control energy efficiency through a market mechanism.

### Denmark

Denmark is the first European country to develop energy labelling of building (Dyrbol and Aggerholm, 2006). The scheme in Denmark started in 1982 and has been mandatory since 1997, under the *Act on the Promotion of Energy and Water Savings in Buildings*. Every year more than 40,000 small buildings (< 1,500 $m^2$) and many large buildings (> 1,500 $m^2$) were labelled (Laustsen and Lorenzen, 2003). The energy labelling schemes are seen as an important way to achieve energy savings in existing buildings in Denmark.

Nevertheless, the actual effect of building energy labels on consumers' behaviour is affected by many social and institutional factors. The research by Gram-Hanssen, *et al.* (2007) showed that Danish people do not use the labels to decide which house to buy; they rather use it to decide what to do with the house when they have bought it. This is an interesting finding about the attitudes.

### United Kingdom

The United Kingdom (UK) followed the EPBD and has adopted relevant standards for implementation of energy certificate and label (BSI, 2008 & 2007). Instead of a solely energy performance certificate, UK has developed a Home Information Pack (HIP) for home buying and selling process, where energy performance certificate to comply with EPBD is a part of the package. The origin idea of HIP was raised in 1997, based on a similar practice in Australia and Denmark while formal HIPs were announced in 2003. Focusing on the energy performance certificate, the national home energy rating scheme (NHER) provides the software modelling, training, accreditation and energy rating services for UK. When Boardman (2004) discussed the new directions for household energy efficiency in UK, it is proposed that the future UK policy should focus on carbon and incorporate feedback.

### USA

The US Environmental Protection Agency (US-EPA) introduced the ENERGY STAR program in 1992 as an indicator of energy efficiency for computers and monitors (Brown, Webber and Koomey, 2002). It is a voluntary labelling program designed to identify and promote energy-efficient products, in order to reduce carbon dioxide emissions. The US-EPA, in partnership with the US Department of Energy (US-DOE), has expanded the program to cover nearly the entire buildings sector, spanning new homes, commercial buildings, residential heating and cooling equipment, major appliances, office equipment, commercial and residential lighting, and home electronics.

The so-called ENERGY STAR label homes program identifies home that is significantly energy efficient than standard home. A home can only receive the label after an accredited home energy rater has performed a third-party verification. The accredited homes must meet strict guidelines for energy efficiency set by the US-EPA: these homes are at least 15% more energy efficient than standard homes and include additional energy-saving features that typically make them 20-30% more efficient than standard ones. In 2007, about 12% of new US housing was ENERGY STAR labelled (US-EPA, 2008); in 2008, it reaches 17%.

Since ENERGY STAR is not well designed for describing whole building energy performance, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has recently proposed a new program to supplement the information gap (ASHRAE, 2009). Though ASHRAE's Building Energy Quotient program (www.buildingeq.com) is still at the initial stage, the theme of calculation methodology, rating methods and implementation recommendations are defined. This is very useful for future development of building energy labels.

**Canada**

"EnerGuide", first introduced in 1978, is the official mark in Canada associated with the labelling and rating of the energy consumption or energy efficiency of specific products (OEE, 2007). EnerGuide labelling exists for appliances, heating and cooling equipment, houses and vehicles. In 1998, the Natural Resources Canada established EnerGuide for Houses which is a labelling and certification programme to persuade and assist customer to make and consider energy efficiency improvements in their purchase decisions. Participating homeowners receive a detailed report on energy consumption, including an energy efficiency rating and a list of recommended energy efficiency upgrades and estimated costs.

In Canada, the international ENERGY STAR symbol complements the EnerGuide Program. EnerGuide allows consumers to compare the energy efficiency of the many different models of household appliances or heating and cooling products. For some of these products, ENERGY STAR goes one step further and identifies specific models that meet or exceed premium levels of energy efficiency (the ENERGY STAR symbol may even appear on an EnerGuide label). For residential buildings, the ENERGY STAR for New Homes initiative promotes energy efficiency guidelines that enable new homes to be approximately 30% more energy efficient than those built to minimum provincial building codes. The EnerGuide rating system enables energy evaluators to determine the energy efficiency of a new home and affix an energy rating label to the home's electrical panel. An EnerGuide label on an ENERGY STAR labelled home tells homeowners what the specific energy rating is for their home.

**Australia**

A House Energy Rating is an index of a building's thermal performance (i.e. heating and cooling requirements) for residential homes in Australia. Separate energy rating schemes are adopted in different states of Australia. Some states, such as Victoria, have sophisticated schemes while some others do not have any. Therefore, the Australian government introduced energy efficiency measures for houses via Building Code of Australia (BCA) in 2003 to those states which did not already have an equivalent system in place.

In most states of Australia, the local council authority will require evidence that a building design complies with energy efficiency regulations. This requires an energy efficiency rating from an accredited energy rating assessor or compliance with the deemed-to-satisfy provisions in the BCA. Indeed, star rating was established in Australia in 1980s. Separate star rating schemes are developed by individual states and the Victoria scheme based on computer program was thought to be the most effective.

Energy rating software is available under the Nationwide House Energy Rating Scheme (NaTHERS), which provides a standardized approach and framework for house energy rating throughout Australia. Though NaTHERS is not mandated, its 'Star Rating' system is recognized as a major measurement for demonstrating compliance with the BCA performance requirements for the energy efficiency. Like other computer software, NaTHERS was not performed well at the very beginning (Kordjamshidi and King, 2009). Continuous development and upgrading of NaTHERS is done to improve the accuracy and reliability of the software tool.

**Singapore**

The "Energy Smart Building Labelling Programme" in Singapore is jointly developed by the Energy Sustainability Unit (ESU) of the National University of Singapore (NUS) and the National Environment Agency (NEA). It aims to promote energy efficiency and conservation in the buildings sector by according recognition to energy efficient buildings that are in the top 25 percentile of the total building cohort. In addition to its energy performance, the building's indoor environmental conditions such as air quality, thermal comfort, ventilation and lighting level are taken into consideration when evaluating a building for the award.

At present, the scheme includes three types of buildings: office, hotel and retail mall (ESU, 2006, 2007 & 2008). An Energy Smart Building Label will be reviewed and assessed every three years, to ensure continued performance and where applicable, continual enhancement in building energy performance.

An online benchmarking system "Energy Smart Tool" (www.esu.com.sg/smarttool.php) can be used to evaluate the energy performances of office and hotel buildings in Singapore. It enables building owners to review the energy consumption patterns within their buildings and compare them against the industry norms. The benchmarking system was developed based on a rigorous study and analysis of two representative databases on office and hotel buildings in Singapore.

**Mainland China**

At present, there is no country-wide energy label for residential buildings in mainland China. Research studies to develop the energy labels were carried out by some researchers (Zhang, Yan and Jiang, 2007) and has been on trial in some cities (such as Shanghai). With the proliferation of building energy efficiency standards for residential and public buildings in China (Hui, 2000; Yao, Li and Steemers, 2005), there is a need to develop effective schemes for building energy labels.

## DEVELOPMENT OF BUILDING ENERGY LABEL

Computer-based building energy simulation is often used to assess/develop building energy labels (Hui, 2002; Rey, Velasco and Varela, 2007). To develop a suitable method for the residential building energy label, a building energy software ENERGY-10 (www.energy-10.com) is used to evaluate the energy consumption and different design factors for typical residential buildings in Hong Kong (Lee, 2009). In our research, the cooking energy is not included because it is difficult to predict and control.

A base case reference building model was developed on ENERGY-10 with the basic information of a residential flat in Hong Kong. The information is established based on the research findings and data from literature, power companies and government statistical information. Representative building design and internal load patterns were used for the model (Wan and Yik, 2004). Typical energy consumption of household appliances is taken from the power companies.

To develop the energy equations for the label, sensitivity tests have been applied to evaluate the different design parameters of the building energy model. The most important parameters have been identified and they are used to determine the rating method for the building energy label.

### Building Energy Equations

The energy consumption of a residential building or flat is a function of different building elements and appliances. The most important factors include: type of building, size of the flat, number of occupants, building envelope design, building orientation, lighting system, HVAC (heating, ventilating and air-conditioning) system and electrical appliances. It is found that the energy consumption could be expressed in the following form:

Energy Consumption = *f* (exterior wall U-value, building orientation, window-to-wall ratio, window shading coefficient, HVAC coefficient of performance, lighting power density, refrigerator energy, hot water energy, miscellaneous appliances energy)

An energy equation for assessing the energy consumption of high-rise residential buildings has been established by using ENERGY-10 simulation results and practical design assessment. The final form of the energy equation includes six major factors, namely, HVAC coefficient of performance (COP), window shading coefficient, lighting power density, hot water intensity, other appliance intensity and refrigerator energy.

Energy Consumption = -21.31 (HVAC COP) + 12.11 (Window shading coefficient) + 2.04 (Lighting power density) + 2.07 (Hot water intensity) + 5.12 (Other appliance intensity) + Refrigerator energy + 73

The results indicate that the HVAC system COP is five times more significant than lighting and hot water appliances, whereas building envelope has a relatively lower impact to the overall energy consumption.

### Rating of Annual Energy Consumption

For clear representation and understanding, the overall building energy performance is distinguished by three grades (A, B and C). Energy consumption of the reference model is assumed to be at the median of the overall residential sector in Hong Kong. The design parameters for the best and worst performance residential buildings are set at 0.5 and 1.5 times of the average value, respectively. The energy consumption line below and Table 1 show the energy consumption range of the proposed energy label.

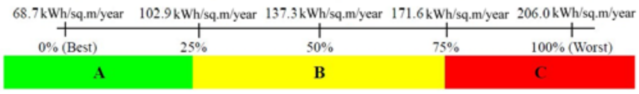


Table 1. Rating of building energy label

| Rating | Percentile | Annual energy use |
|---|---|---|
| Grade A | First 25 | < 102.9 kWh/m$^2$/year |
| Grade B | 25 to 75 | 102.9 to 171.6 kWh/m$^2$/year |
| Grade C | Beyond 75 | > 171.6 kWh/m$^2$/year |

For each individual parameter, a set of rating for evaluating the performance has been established as shown in Table 2. The effects of cross ventilation and air-conditioning operation period have been considered by a simple rating based on practical experience.

Table 2. Rating of individual parameters

| Parameter | Grade A | Grade B | Grade C |
|---|---|---|---|
| Wall U-value (W/m$^2$.K) | < 4.5 | 4.6 – 6.5 | > 6.5 |
| Window-to-wall ratio (%) | < 16 | 17 – 25 | > 26 |
| Window shading coeff. | < 0.5 | 0.5 – 0.9 | > 0.9 |
| HVAC COP | > 3 | 2 – 3 | < 2 |
| Lighting power (W/m$^2$) | < 7 | 7 – 12 | > 12 |
| Hot water intensity (W/m$^2$) | < 7 | 7 – 12 | > 12 |
| Other appliances (W/m$^2$) | < 9 | 9 – 14 | > 15 |
| Cross ventilation (% rooms with windows at opposite directions) | > 70% | 40 – 70% | < 40% |
| Air-conditioning operation period (months) | < 5 | 5 – 6 | > 6 |

The proposed design of the energy labels for residential buildings has been evaluated through survey questionnaires on some selected professionals. Feedbacks were collected to improve the label design and rating system. The final form of the building energy label is shown in Fig. 5. The overall rating including the grade and consumption level is shown on the top and the sub-grade results are given at the bottom.

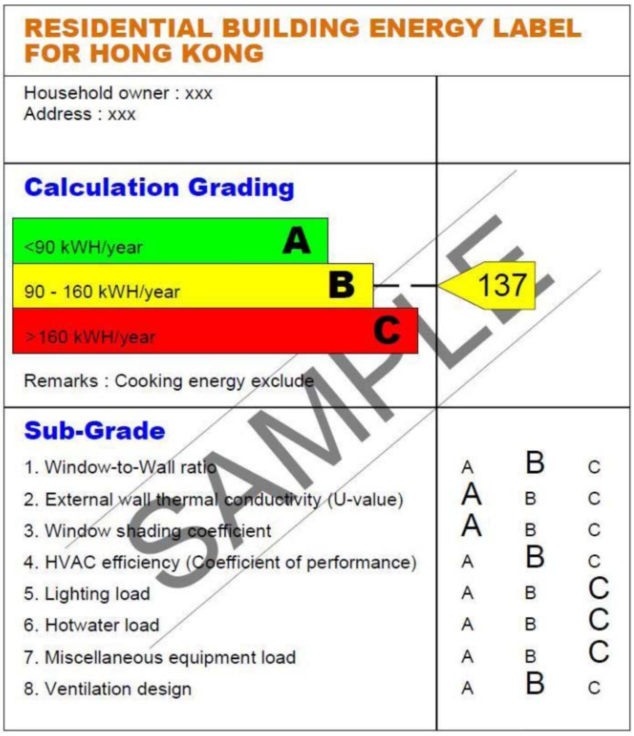


*Fig. 5. Proposed residential building energy label*

## DISCUSSIONS

The primary objective of building energy label is to enhance energy efficiency and minimize energy consumption in building sector through market forces (CLER, 2003). The labelling scheme provides a reliable and applicable way to implement energy certificate based on suitable ratings. The certificate makes building performance visible and provides incentives for energy improvement.

Energy labels would effectively differentiate products in the marketplace. They provide information on the potential and actual energy use of buildings, as well as feedback to building owners and managers on how their building is performing (ASHRAE, 2009). The idea of energy labels on buildings follows the logic of other types of labels and consumer advices. It is a method based on the assumption that well-informed actors will behave rationally.

### Appliance Energy Labels

Kempton and Layne (1994) have studied the consumers' energy analysis environment and found that their analytical efforts and capabilities are limited. This often degraded decision quality and created a market barrier to energy conservation.

Wiel, Egan and Cava (2006) pointed out that energy efficiency standards and labels provide a solid foundation for economic growth, climate change mitigation, and regional trade. Appliance energy labels have been widely used in many countries; they are effective policy instruments to help increase awareness and overcome the market barriers to energy efficiency.

Appliance energy labels allow consumers to make informed choices about the products they buy and to manage their energy bills (IEA, 2000). Experience of appliance label provides valuable and precious insight for introduction of building energy label. For instance, Wiel and McMahon (2003) discussed how governments should implement energy-efficiency standards and labels. They described the typical steps for developing appliance energy-efficiency labels, some of which are also useful for building labels.

Step 1: decide whether & how to implement energy labels
Step 2: develop a testing capability
Step 3: design and implement a labelling program
Step 4: analyze and set standards
Step 5: maintain and enforce compliance
Step 6: evaluate the labelling program

### Energy Policy Instruments

Energy efficiency labels work best in conjunction with other policy instruments designed to shift the market toward better energy efficiency (Wiel and McMahon, 2003). Usually, energy efficiency standards eliminate the least efficient models or practices from the market. Other energy policy instruments, such as energy labels, incentive schemes and information programmes, help to further transform the market toward higher energy efficiency.

It is crucial that building tenants or consumers receive consistent messages on energy efficiency that reinforce each other. When working together effectively, these policy instruments can accelerate the penetration of energy-efficient technology throughout the market. In fact, they can influence building design and procurement, purchase decisions, operation and maintenance of buildings and related energy-consuming products in our society.

### Building Energy Rating Methods

A critical issue in developing building energy label is the rating methods for assessing energy performance of buildings. In general, three approaches can be used to formulate the building energy rating (CLER, 2003):

- Thermal dynamic simulation tools
- Simplified calculation methods
- Points-based methods

As shown before in the residential building energy label for Hong Kong, building energy simulation is applied for setting the building energy equations which form the basis of the rating method. Other factors might be considered by integrating practical design assessment into the rating. Often, the analysis results can provide insight into the value and potential long-term energy costs of the building.

To evaluate building energy performance at design and operation stages, ASHRAE (2009) proposed two types of rating for building energy label:

- *As-designed Rating (asset)* provides an assessment of the building based on the components specified in the design. The asset rating is based on the results of a building energy simulation model. It is applicable to both new and existing buildings.

- *In-operation Rating (operational)* provides information on the actual energy use of a building and is based on a combination of the structure of the building and how it is operated. It is applicable for existing buildings and after 12-18 months of operation for new buildings.

In principle, the operational rating may also be established with reference to the actual energy consumption data obtained from building energy audit carried out by an energy rating assessor.

## CONCLUSIONS

Building energy label can be considered as a market transformation tool for energy efficiency. From the worldwide review, it is found that appliance energy labels are widely used in many countries. Some countries, such as Australia, Canada, Denmark, Singapore, U.K. and U.S.A., have extended them and developed energy labels for buildings; their strategies and experience are useful to Hong Kong and other economies. In Europe, with the launch of the EPBD in 2002, energy certificates are being set up and applied to grade all new and existing buildings in terms of energy performance. Similar approach is being taken by USA, mainland China and other countries to facilitate energy conservation and awareness, with the aim to "change" consumer and investor attitudes.

A label conveys the information; certification is a process to keep the information consistent. It is believed that there is no perfect way to implement the energy certification in buildings; the critical issue is how to determine the rating methods for assessing the building energy performance. In order to ensure effective implementation and achievement, the building energy label must work together with other energy policy instruments, such as energy efficiency standards, incentive schemes and information programmes.

The characteristics of energy consumption of typical residential buildings in Hong Kong have been studied. An energy equation for assessing the energy consumption of high-rise residential buildings has been established by building energy simulation method and practical design assessment. The final form of energy equation includes six major factors, namely, HVAC COP, window shading, lighting power density, hot water intensity, other appliances intensity and refrigerator energy.

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