Buildings' Energy Efficiency and Buildings' Energy Codes: a Literature Review

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Abstract

International concerns in relation to energy conservation began to emerge during the oil crisis in 1973. At this time attention focused on how to conserve this non-renewable energy source. Since then the buildings has been considered as high potential of saving energy, thus improving the energy efficiency of buildings became an important aspect of conservation. It attracted interest from the relevant bodies in the developed countries where, as a result, building energy codes were developed. During the late 1980s and 1990s, the economic imperative for energy conservation began to diminish due to the dropping of oil prices to pre-1970s levels. Gradually the environmental concerns replaced the economic ones. This was enforced by the call to reduce the green house gases emission to protect the environment from the potential danger of climate change. The environmental aspect has driven the recent development of the building energy codes aiming to reduce CO_2 emissions. The distinctive features of each community determine the detailed aspects of the building energy codes; the codes should therefore reflect the cultural and political context of the targeted community. Learning from others experiences represent the first step towards creating successful building energy codes.

Key Words: Efficiency, Building's Energy Codes, Climate Changes

1. Introduction

Before 1970s the main concerns of the building codes were to ensure the health and safety of the occupants of the buildings. Since the oil crisis in 1973 reducing the buildings consumption of energy started to be given a priority through the building energy codes in the developed countries. In the USA the Congress enacted the Energy Policy Conservation Act in 1975; accordingly ASHRAE issued the first building energy standards in 1975. The energy efficiency policies and programs have been initiated in the European Union in 1970s. UK, Denmark and Germany have developed and implemented their BECs for the last three decades; to date around 17 European countries have their BECs in use (Deringer, et al., 2004).

In 1990s the worldwide concern of the impact of the GHG on the earth environment, have enhanced the earlier call for reducing the consumption of energy, accordingly the building energy codes have been refocused. This call initiated another revision for the building energy codes in the developed courtiers. The revised codes aim to reduce the emission of CO_2 from the building sector (Todd, 2001; Todd, 2006).

Janda study had explored the status of the building energy codes in 81 countries, this study represent an update for his previous study conducted in 1994 the study have showed that there is a continuous increase and concern towards the building energy codes, thus one-third of the world's countries have developed building energy codes, Fig 1 shows the percentage of the existence of thermal building regulations in different regions worldwide, (Janda and Busch, 1994); (Janda, 2008). Deringer, 2004 explored the reasons behind the failure of the building energy codes in achieving their targets in the developing countries (Deringer, et al.,2004).

This study aim to present the role the building energy codes had played worldwide in improving the buildings' energy efficiency. In order to build on others experience in this important field.

2. Buildings and Energy

2.1 Buildings' Energy Consumption

Buildings consume almost 40 percent of the primary energy in most countries and are one of five main users of energy (WBCSD, 2010); Fig 2 shows that the architecture is responsible about 48% of energy consumption in USA.. The Buildings consumption of energy can be reduced by improving their efficiency (Lee and Yik, 2004). Many previous technical studies had demonstrated the potential of the built environment in saving energy (Kasabov, 1979). Thus, international effort has focused on this important sector in attempt to reduce energy use.

The oil crisis in the 1970s was the main motive for developed countries to reduce the consumption of energy, there was a serious attempt within these countries to find a solution. They started in two ways: reducing the use of energy (demand side) and trying to find another source of renewable energy (supply side). Creating Building Energy Codes (BECs) was one of the policy instruments used by the developed countries to reduce the consumption of energy in the building sector (Deringer, et al.,2004); (IEA, 2005); (Koeppel and Ürge-Vorsatz, 2007); (Janda and Busch, 1994). Nadel's research in (1997) showed that the use of energy efficiency standards was increasing continuously and being updated periodically (Nadal, 1997).

Climate change has promoted further concerns regarding buildings' impact on the environment, accordingly the BEC formed the basis of energy and environmental policy in the 1990s, since improving buildings' efficiency attempts to control the growth of CO_2 emissions by reducing their consumption of energy (Lee and Yik, 2004).

2.2 Problems Resulting from the High Usage of Energy in Buildings

The increased usage of energy in the building sector with the continuous increase of new buildings contributes to the potential for climate change. The environmental impact of building is widely acknowledged and in the past three decades progress has been made in developing ways to reduce this (Roaf, 2004), Fig 3 shows the world carbon dioxide emission.

The majority of the energy used in buildings is from non-renewable finite sources that are diminishing rapidly. By operating at optimum efficiency and minimizing the wastage of energy, these resources can be retained for further generations. At the same time buildings must be capable of providing occupants with the reasonable comfort levels in the absence of energy.

In addition to the above, the economic factors cannot be neglected, as the economy drives our life and is strongly dependent on the price of oil. Saving energy is beneficial for both the end users and the economy of each country. Improving the energy efficiency of buildings would results in savings on energy bills for the occupants. Additionally, these improvements would reduce electricity peak load, thus reducing the country's need for new power stations, and resulting in savings that could be used for other important human development.

3. Buildings' Energy Efficiency

Improving the buildings' energy efficiency does not mean a decrease in the standards of indoor comfort; it is a call for an efficient use of the energy to reduce waste and to reduce the required amount of energy to achieve those standards. In short "efficiency involves reduced energy consumption for acceptable levels of comfort, air quality and other occupancy requirements, including the energy used in manufacturing building materials and in construction" [16,p.7].

There is no specific definition of the Energy Efficient Building; this term has been used to describe a variety of buildings worldwide (Lowe and Bell, 2000). According to Meier et al. (2002) an energy efficient building must be above the average of the following aspects: firstly the equipment used must be efficient and the materials suitable for the climate conditions, secondly, the amenities and services provided must fulfill the building use, and finally the consumed energy of the building must be lower than similar buildings. In addition, he considered the embodied energy in both construction and demolition of the buildings as the fourth important aspects to be considered in the future (Meier et al., 2002).

There is no standard scale to measure the buildings energy efficiency; it is a terminology with a variable scale that depends on the type of building, climate and the common practice of the local construction industry.

3.1. Assessing buildings energy efficiency

Evaluating the energy efficiency of the buildings is not a straightforward task, as the buildings consumption of energy is the result of a complex interaction between the building, climate and user (Roaf, 2004).

The building's energy performance is the main indicator of their energy efficiency. The literature recognizes two means for evaluating the energy performance:

1. The building's performance as compared to other standard building;
2. The use of simple performance indicators such as the annual energy consumption of the buildings per floor area and comparing it to a target value which represents the maximum energy budget of the building.

The methods used to assess a building's thermal performance must be monitored carefully to ensure they reflect the actual thermal performance of the buildings (Casalsl, 2006). The maximum energy budget for buildings has been used as a means to improve the building's energy efficiency. A building energy budget represents the maximum accepted value for the building's consumption of energy. According to Casals (2006) the proper indicator used to evaluate the energy performance of the buildings should be able to: a) quantify the need of energy of the buildings, expressed for example in terms of kWh/m2 per year; b) consider the primary energy consumed by the building; c) analyze the energy life cycle; d) limit the energy supply of the building (renewable and non renewable); and e) encourage the use of renewable energy (Chwieduk, 2003). The indicators in use worldwide for both the regulations and the certification exclude the embodied energy and the life cycle, while both are significant in assessing the energy performance of the building. The analysis of life cycle is believed to consider the effect of buildings on both the environment and energy; it considers the different elements, the materials and systems of the building through the process (Carlo, et al., 2003).

3.2 Rating Systems

The rating system aims to provide a framework to assess the overall building performance, thus fulfilling the increasing concern towards more sustainable/green buildings (Pérez-Lombrad, et al., 2009). The rating system considers the whole building performance including its life cycle. Generally, it covers the following five aspects of the building design and life cycle: site, water, energy, material and indoor environment (Gowri, 2004). A number of rating systems have been proposed and developed worldwide to gauge the performance of the buildings (Pérez-Lombrad, et al., 2009). The following three rating systems represent the basis on which the different existing rating systems have been developed worldwide (Gowri, 2004).

Firstly, the Building Research Establishment Environmental Assessment Method (BREEAM) was initiated in 1990 by the British Research Establishment. BREEAM has been widened from a checklist to a comprehensive assessment tool. BREEAM has identified the benchmarks for assessing the environmental performance of buildings by the UK building industry (BREEAM, 2009). A variation of BREEAM was developed to suit the local requirements in Canada, Australia and other European Countries. BREEAM Canada and BREEAM GreanLeaf represent two examples of the adapted version of BREEAM which are used in Canada, (Gowri, 2004), and recently the Hong Kong Building Environmental Assessment Method (HK-BEAM) represents the adapted version of BREEAM for Hong Kong usage (Davies, 2001; Lee, et al., 2007).

Secondly, the Green Building Challenge Assessment Framework (GB), resulted from collaboration work between 20 countries, its first draft was completed in 1998. They developed a spreadsheet tool (GBtool) which could be adapted according to each country's priorities (Gowri, 2004).

Thirdly, the Leadership in Energy and Environmental Design (LEED) was developed by the U.S. Green Building Council. Since releasing Version 2.00 in 2000 it has gained recognition. Originally it was planned for new commercial buildings but its success highlighted the need for adapting the rating for existing buildings as well (Gowri, 2004).

Although the rating systems were originally voluntary, there has been a recent shift towards considering them as mandatory requirements, such as the EEPBD requirements for Energy Performance Certificate (European Union, 2002); hence, in the UK starting from 2007, the energy rating became an important part of the house-buying process (Todd, 2006). The rating systems for buildings are based on a normalisation procedure, the definition used for normalisation have a substantial impact on the building ranking. For example the use of total consumed energy would reflect the environmental concerns better, while Litt and Meier's study (1994) favours the use of the largest end uses of the building energy, which would be the cooling for hot regions and heating for cold regions.

3.3. Use of Simulation Programs

The use of simulation programs was recognised as a valuable tool in the buildings evaluation process, in addition to their use in the development process for the Building Energy Codes (BECs) worldwide (Beausoleil-Morrison, et al., 2001).

The simulation programs are used to find the building's consumption of energy, because the simple analyzing tools fail to gauge the actual energy performance of the buildings which have a complicated energy system, where the different building systems interact together, along with the external environment and the user interaction (Chwieduk, 2003). This difficulty is more highlighted when considering a bioclimatic approach to the design of building, the building energy analysis tools presented by the simulation tools, are capable of handling the complexity of the building's thermal interaction (Chen, et al., 2006); (Chiraratttananon, Taweekun, 2003).

3.4. Barriers to Energy Efficiency

The barriers to energy efficiency have been discussed widely in the literature to explore suitable policy measures or to find out the reasons behind the failure of implemented measures (Deringer, et al., 2004; Vine, 2005). The barriers in the buildings sector are found to be more than in any other sector (Koeppel and Ürge-Vorsatz, 2007). The most important barriers in the building sector as identified in the literature are summarised below.

A number of structural barriers exist in developing countries that hinder the successful adoption of energy efficiency in buildings; these are the lack of governmental financial support and appropriate policies, low energy prices, the lack of coordination between different organizations and the absence of suitable infrastructure (Balce and Zamora, 2000). Moreover, the corruption, ineffective implementation of the policies, lack of interest between governmental bodies, and lack of experience in the developing countries present other political and structural barriers (Koeppel and Ürge-Vorsatz, 2007).

The high capital cost of efficient technology is considered the main economical barriers towards the use of energy efficient technology (Carbon Trust, 2005; Levine, et al., 2007; Caird, et al., 2008). This is highlighted in the developing countries where the high cost of the energy efficiency technology is believed to be paid back over many years (Koeppel and Ürge-Vorsatz, 2007; Balce and Zamora, 2000).

In the developing countries, the restricted funds where the payback period is uncertain represent a financial barrier towards energy efficiency (Balce and Zamora, 2000). The low cost of energy due to governmental subsidies is another important economic barrier to energy efficiency which hinders the promotion of energy efficiency measures (Koeppel and Ürge-Vorsatz, 2007; Levine, et al., 2007). The low cost of energy is considered a major barrier in developing countries (Alam, et al., 1998; Balce and Zamora, 2000) where the energy cost is a small part of the expenditure on homes (Nässén and Holmberg, 2005).

Technical barriers exist in developing countries where there is a lack of experience, knowledge and information, along with the limited support and after sale services. The absence or shortage of the energy efficient products and expert personnel, in addition to lack of information with regard to the advantages of such technology, hinders their use (Balce and Zamora, 2000).

Market failure represented by the ineffective distribution of costs and benefits between the different stakeholders or misplaced incentives is an important barrier in both developed and developing countries. The building owner pays for the energy efficiency measure while the tenant (end user) benefits from the efficiency measures (Nässén and Holmberg, 2005; Levine, et al., 2007; Koeppel and Ürge-Vorsatz, 2007; World Business Council for Sustainable Development, 2007; Balce and Zamora, 2000).

The attitude of the users and their lifestyle are considered a cultural barrier to energy efficiency (Balce and Zamora, 2000; Levine, et al., 2007). In developing countries the lack of awareness of the means of conserving energy and the importance of saving energy is a major barrier (Koeppel and Ürge-Vorsatz, 2007).

3.5. Policy Mechanism to Adopt Energy Efficiency Measures in Buildings

There are two main approaches to conserve energy in buildings: the technical and the political. The technical approach guides the designers of the buildings towards the more efficient and effective energy-using designs and techniques. While the political approach, enforces the use of specific measures that is considered effective to reduce the buildings consumption of energy. Different policy mechanisms have been implemented worldwide to improve the energy efficiency in buildings. The literature identified the following mechanisms used (OECD, 2002); (IEA, 2005); (Janda and Busch, 1994):

- Mechanisms that control and regulate the energy efficiency in buildings. These mechanisms are subdivided into normative and informative regulatory mechanisms. The BECs are an example of the normative type which must be followed. While the informative mechanisms provide the end-user with information which he is not forced to consider, such as labeling programs.

- Mechanisms that consider the economic and market methods, these had voluntary elements.
- Mechanisms that employ fiscal and incentive tools to conserve energy in buildings. This mechanism is applicable for different sectors and technologies.
- Mechanisms that provide information and support to increase the public awareness and enhance voluntary work.

The policy considered by the governmental bodies can significantly influence the building's consumption of energy; hence affect its environmental impact. Thus the nature of the different policy instruments must be understood by the policymakers, so they can chose the most suitable mechanism to achieve efficient policy package. Moreover, the local conditions have a significant impact on the building design and activities, a big difference in the building techniques exists between the regions, predictably these local factors will influence governmental policies. In order to transfer the market towards better energy efficiency it is recommended to combine different policy instruments ((Wiel and McMahon, 2003)).

Harmelink et al.'s study (2008) has identified the following four main points that contribute to the success of the policy instrument used (Harmelink, et al., 2003):

- The policy instrument should have definite objectives; also the implementing organization should be authorized;
- The instrument should be competent of balancing and combining the elasticity and stability;
- The stakeholders should be involved in the selection of the instrument; and
- The instrument should be capable of adapting and incorporating new policies.

There are two main ways to implementing energy efficiency measures in buildings, mandatory or voluntary. The mandatory codes are a straightforward way of restricting the behaviour of people and organizations to achieve objectives; this tool has been used to control the energy use in building since the mid-70s. They are the most widely adopted and used in over 30 countries and regions. Some developing countries started to use them in the 1990s (Lee and Yik, 2004). The voluntary programs are used to tackle energy or environmental problems which cannot be solved easily by regulations. These instruments include codes and eco-labeling schemes in which organizations commit to making their products or production processes more environmentally friendly (Barde, 1995). Since 1990 the use of voluntary approaches has increased to deal with environmental problems which include GHG emissions (OECD, 1999).

4. Buildings' Energy Codes

The Building Codes or regulations are a form of regulatory instruments, they are defined as the documents used by local state or national government bodies to control building practices through a set of statements of acceptable minimum requirements. As these requirements are based on socio-political and community consideration, they differ from country to country or from locality to locality (Walker, 1997). The BECs are used by the government bodies to improve the building's energy efficiency, hence achieving a positive change to the social, economic and environment in society. BECs are found to be the most effective and cost-effective regulatory instrument that lead to an improving the energy efficiency of buildings thus reducing the emission of GHG (UNEP, 2007).

On the other hand, the building standards are a set of technical documents that standardize in terms of quality or performance and sometimes in terms of size or procedure some activity in relation to building construction (Walker, 1997).

4.1. Building Energy Code and Energy Efficiency

The survey of Janda and Busch in 1994 showed that there is an increased international concern over energy standards as part of their energy efficiency agenda (Janda and Busch, 1994). Levine et al. (1995) also found that countries on almost every continent were now in various stages of developing, improving, and expanding their BECs (Levine, et al., 1995). The majority of developed countries considered the use of BECs an effective policy towards saving energy.

The BECs played a significant role in the improvement of energy efficiency of new buildings in most of the OECD countries (OECD, 2002).

Moreover Schipper's et al. study (1986) found that most studied countries had shown a decline in their energy demand from 1973 to 1984. This decline is believed to be related to the BECs which have been enforced since 1973 (Schipper, et al., 1986).

The BECs has seen a significant development along with the rapid growth of other instruments (Deringer, et al.,2004); (IEA, 2005); (Koeppel and Ürge-Vorsatz, 2007). Since 1970s around 30 developed countries had established and implemented their own regulations (Janda and Busch, 1994); (Deringer, et al.,2004). The improvement in the calculation methods, computer modeling, and building research over the past two decades provide the necessary tools for developed countries to revise their original standards.

Moreover, the increasing awareness of the impact of climate change on our environment has boosted further development of the BECs. Consequently, third and fourth generations of BECs are under revision in a number of countries like USA and Canada (Deringer, et al.,2004); (WEC, 2004). The BECs were found to be one of the most effective and cost effective in reducing GHG emission (Koeppel and Ürge-Vorsatz, 2007); (WEC, 2004). The ASHRAE standards (90 series) are the most widely adopted model nowadays, the methods proposed in the current and previous versions of the standards have been commonly used in many locations of the world, and it was the basis for the codes in a number of developing countries (Janda and Busch, 1994); (Levine, et al., 1995).

4.2. Types of Building Energy Codes

There are two main forms of codes and regulations, prescriptive and performance (Hitchin, 2008). Under those two categories the World Energy Council identified the following types of the building codes: a) envelope component, b) overall envelope, c) limiting heating and cooling demand, and d) energy performance. Limiting the heating and cooling needs and the energy performance are the two approaches recently preferred; both approaches are of the performance type.

4.2.1. Prescriptive Codes

The prescriptive approach is based on providing a detailed description of the building's technical requirements. In this approach the regulations specify the minimum requirements for different building components, which the buildings have to comply with to satisfy the code. The requirements are chosen based on their suitability for the climate and capability to save energy. The regulations might differ in the building component they target (the building envelope, lighting, heating ventilation and air-conditioning, electrical power, lifts and escalators and service water heating), also they differ in the stringency level of their requirements (Koeppel and Ürge-Vorsatz, 2007).

The main advantages of the prescriptive codes are that they are simple to use and follow, they are straightforward for builders or designers to follow, easy for third parties to check and relatively easy for building regulations to enforce (Hitchin, 2008). While their disadvantage is that they tend to limit development of new technology and techniques, this might serve as a barrier for innovation and make the regulations very restrictive, so they do not encourage innovative design solutions. This would limit exploitation of the different passive cooling or heating techniques, because prescriptive codes are not able to consider the interaction between the building system and the measures that would optimize performance.

4.2.2. Performance-Based Codes

The performance-based approach is based on describing the required performance of the building without specifying how to achieve it. This approach has been used by a number of developed countries in their building energy codes (ICC, 2006); (ASHRAE, 2007), and others are in a process of developing this approach in their building codes.

The performance-based code fulfils the need for a more flexible approach (Meacham, et al., 2005). The main advantages of using such an approach are believed to be:

- offers greater flexibility and encourages creative solutions and innovation of new materials (Hui, 2002); (Brochner, et al., 1999); (Marshall and Petersen., 1979), also it allows for design flexibility and can consider innovative features such as day lighting, passive solar heating, heat recovery, better zonal temperature control, thermal storage, off peak electrical energy, etc (Hui, 2002);
- reduces the cost as it promotes creative new solutions to improve the energy efficiency of buildings; and
- concentrates on quality rather than price only (Brochner, et al., 1999).

The use of stronger performance based approaches for establishing the building code was highly recommended in Deal and Fournier's study (2001) the use of performance based approach will "raise the overall standard for code development….encourage more regionally based design and construction solutions…..promote better quality solutions….and…..less confusing"(Deal and Fournier, 2001).

On the other hand, managing and acquisitioning the technical, environmental and administrative knowledge is believed to be one of the disadvantages of this approach, along with the administrative cost (Brochner, et al., 1999). Moreover, the buildings' performance over time represents one of the technical problems related to the performance approach, because the performance of innovative solutions over time is not known. The performance of the traditional prescriptive solutions has been well investigated and confirmed [54]. Additionally, it is easier for the architects to follow prescriptive codes especially for typical low cost projects.

Using the performance approach in the building energy codes requires setting an energy budget for the targeted buildings, the buildings' annual energy consumption (heating, lighting, cooling, etc.) is generally the value used in this context. The performance-based code cannot be directly transferred from developed countries to developing countries; the implementation process for such codes in developing countries requires detailed guidance for construction techniques and materials selection, where a number of local issues must be considered before implementing it. The advancement of the local codes must consider the: contents, approval process, compliance procedures, verification methods and certificates and professional involvement. All these will have an impact on the implemented codes and their mixture of prescriptive and performance-based approaches [55]. Performance-based regulations require a high degree of skills in both the administrative bodies and the designers, the simulation programs are considered an essential tool in this approach as a means to show compliance with the codes (Hui, 2003a). Accordingly, the use of such approach in developing countries obliges establishing the required skills and institutions beforehand (Hui, 2002).

4.2.3. Overall Thermal Transfer Value (OTTV)

This approach is considered a partial performance method, which is based on describing the required performance of the building envelope. This approach limits the OTTV value for the building envelope as an indicator for the building's energy consumption; it is used to control the design of the building envelope to reduce the external heat gain through it, which will lead to a reduction in the electricity required for cooling the buildings. It acts as an index to compare the thermal performance of buildings. This method is more suitable for application to buildings in hot climates, because it accounts for solar heat gain through the envelope [56]. It measures the average heat gain through the three major components of the building envelope: the conduction through opaque walls, the conduction through window glass, and solar radiation through window glass. Usually there will be two sets of OTTV one for the exterior walls and the second for the roof (Hui, 1997). This method was first proposed by ASHRAE based on the main significant factors that affect the thermal gain of the buildings.

The related authorities set the required OTTV value which the buildings must not exceed in order to satisfy the code. Whilst ASHRSE stopped the use of the formula in the 1980s, the ASEAN countries continued to use and develop it as a measure in their energy code, where each country considered the use of this method revised the formula to suit their region. This development was carried out under the ASEAN-USAID building energy conservation Project (Chirarattananon, et al., 2004). Also teamwork between Egypt and USA developed the Egyptian building energy code and their OTTV formula [64]. Hong Kong developed their own OTTV formula as part of their building energy code, and started to use it in 1995 for new commercial and hotel buildings (Hui, 1997).

4.3. Importance of Building Energy Code

The literature emphasized the impact of improving the energy efficiency to control the growth of Co2 emission. The BECs are one of the most effective regulatory instruments, which are capable of improving building's energy efficiency, thus reducing the building's emission of GHG (Koeppel and Ürge-Vorsatz, 2007). BECs promote designing and operating energy efficient buildings. Furthermore, it pushes the different parties involved in the construction industry to develop building products and services that save energy (Janda and Busch, 1994); (Hui, 2002).

BECs would increase the public awareness regarding conserving energy in buildings. In addition, the BECs would help to form the basis for building performance assessment and energy efficiency program development (Janda and Busch, 1994); (Hui, 2002).

Finally, successful BECs would be capable of overcoming the majority of the barriers that hinder delivering the energy efficiency techniques in the building sector (Koeppel and Ürge-Vorsatz, 2007). The regulation is the measure that will force the construction industry to adopt energy conservation techniques (Guy, et al., 2001).

5. Conclusions

There has been world concern regarding improving the energy efficiency of buildings since the oil crisis in 1973, with buildings being identified as one of the five main energy consumers worldwide. The building's energy performance is the main indicator of buildings' energy efficiency. Thus, the indicator used to evaluate the energy performance of buildings is considered a significant element for building regulations. Simulation programs were recognized as a valuable tool in the buildings evaluation process, they are used to find the building's consumption of energy. In addition to their use in the development process for BECs worldwide.

Different policy mechanisms have been implemented worldwide to improve the energy efficiency in buildings. The BECs are found to be the most effective and cost-effective regulatory instrument that lead to improving the energy efficiency of buildings. The requirements of the BECs are based on socio-political and community consideration, thus they differ from country to country. The literature showed increased international concern over energy standards as part of their energy efficiency agenda, it was found that countries on almost every continent were now in various stages of developing, improving, or expanding their BECs.

There are two main forms of codes and regulations, prescriptive and performance. The performance-based approach has been used by a number of developed countries in their BECs, and others are in a process of developing this approach in their building codes. OTTV is considered a partial performance method; it is more suitable in hot climates, because it accounts for solar heat gain through the envelope.

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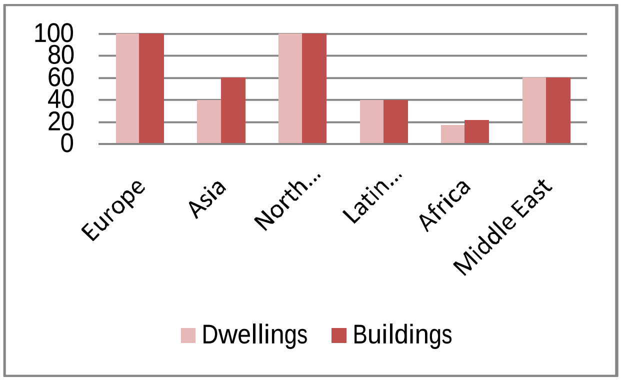

Fig. 1: Thermal Building Regulations (Moisan, 2005, p. 12)

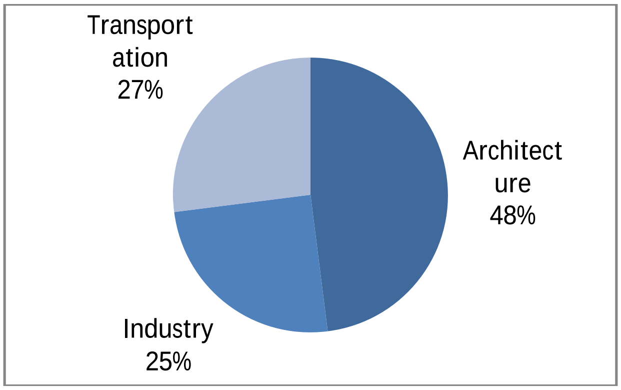

Fig. 2: Energy Consumption (Mazria, 2003)

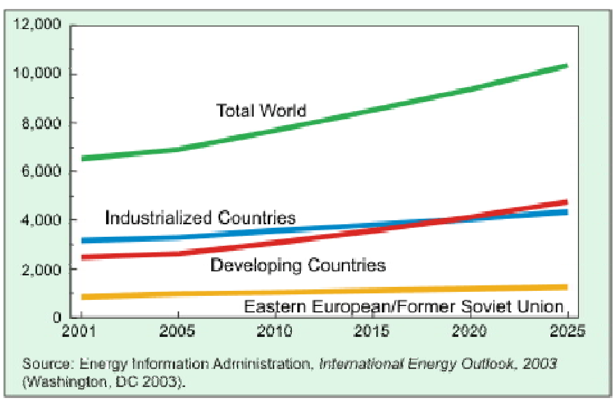

Fig. 3: World Carbon Dioxide Emissions by Region, 2001-2025 (Million Metric Tons of Carbon Equivalent) (EIA, 2003)