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ORIGINAL RESEARCH PAPER

Study of Zero Carbon Buildings and Policy Principles in Residential Environment for Sustainable Development

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ABSTRACT: Nowadays, many countries have taken measures and policies for development of zero or low carbon buildings. Regarding the technological advancements from one hand and increase of problems from the other hand, sustainable development has been recognized as one of the priorities on developed countries. Sustainable development is a new platform considering politics and culture and at the same time emphasizes on economy, trade and industry and also supports environment, nature and equality of human rights. Building can bring various advantages and disadvantages for our society and environment. Therefore, the main objective of the present research is to investigate the main concepts of carbon-zero buildings in order to reduce energy consumption in buildings. In this way, effects and logic of carbon application has been recognized as an index of sustainability. The methodology of this research is analytical and documental research method. The results of research show that, Improvement of buildings energy efficiency by technological, supervision, voluntarily and financial encouragements is desirable. As urban areas have high potential for improvement of energy efficiency, low carbon buildings, in addition to building technology, residential environments with low carbon have to be designed in urban areas and Spatial planning can also play an important role in guiding the building sector to use lower amount of carbon.

Keywords: Zero carbon, Zero energy, Zero carbon buildings, Policy making, Sustainable development

INTRODUCTION

To achieve sustainable development and cope with climate change, development of cities and communities with low carbon is now a global trend (ADEME, 2010)(DCLG, 2007)(NIES, 2009)(Zuo, *et al.,* 2012), low or zero carbon design is necessary for carbon reduction purposes (Brown, 2010). Among all the sections, buildings are one of the largest greenhouse gas (GHG) emission sources as these gases are sub-production of electricity consumption which is highly applied in buildings. Also, buildings provide the highest opportunities for GHG reduction (IPC, 2007). Recently, many countries have adapted policies and measures to develop low or zero carbon buildings by displaying projects to reduce carbon emission and its environmental consequences (ASBEC, 2011)(Pan and Ning, 2015). Energy efficiency and reduction of carbon emission in buildings is now an important issue in global level (Boake, 2008; Hui, 2012, Loper, *et al.,* 2008). Legal tools have been employed throughout the world to improve cost-effective buildings in terms of energy consumption with low carbon. Without cooperation of the government or supporting policies, development of such buildings to reach to the predicted goals will be very slow.

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MATERIALS AND METHODS

In few years One of the most important challenges in the world is the energy issue. In field of Energy saving and environmental conservation are among the issues, it is one of the things to be considered when using renewable energies. Today, due to increased pollution by Fossil fuels The use of renewable energies is important. In this context, the idea of zero energy buildings in sustainable architecture and urbanism has attracted international attention The benefits of such buildings will increase energy efficiency by saving energy and minimizing waste. The use of existing natural resources and their use will have a crucial role to play in preserving the environment and continuing it for future generations. The method of this research is analytical and documental research method that explains the content and performance mechanism will focus on the current urban environment. The results of this research based on analytical documents show that this point can be emphasized Urban areas have high potential for buildings and residential areas energy efficiency. Spatial planning can also play an important role in guiding the building sector to use lower amount of carbon.

Literature review

Zero carbon buildings

The terms of zero carbon or zero emission are used for buildings which use renewable energy resources; therefore, in a year, the net produced energy in that site is equal to the net required energy on that building. Studying of zero carbon building (ZCB) is crucial as its meaning and concepts are sometimes undetermined which may lead to incorrect understanding of them (Hui, 2010).

Zero energy and zero carbon buildings

Zero energy building (ZEB) is sometimes used in relation with ZCB. ZEB can be representative of a building which consumes the same amount of energy which is produces annually. Torcellini et al (2006) provided 4 definitions for ZEB: net zero energy in the site, zero net energy resource, zero net energy cost and zero net energy emission. Also the options of a classification system based on renewable energy consumption were used to separate different types of ZEB. Table1 shows a summary of the terms and definitions. Recently, researchers and governments have investigated numerous definitions for ZEB and ZCB to develop an international census and definition (ASBEC, 2011)(DCLG, 2008)(ECEEE, 2009)(Fulcrum, 2009)(Marszal, *et al.,* 2011)(Sartori, *et al.,* 2012)(UK-GBC, 2008).

They all agree that ZEB and ZCB development can control carbon emission and improve building performance. Generally, ZEB only differs with design of ZCB where there is higher concern in relation with reduction of energy performances of a building. By zero emphasis on application of fossil energy and by application of renewable and low carbon energy resources, the emission of carbon by the buildings can reach to equilibrium.

Buildings energy consumption

A building consumes energy in all stages of its life in infrastructure, production, material transportation, construction, operation, renovation and deconstruction and can emit GHG (UNEP, 2007). Energy consumption patterns of the buildings and emission of GHG can be affected by different factors such as geographical position, population size and in national levels.

Term	Definition
Zero energy building or net zero energy building (NZEB)	A building which consumes the same amount of energy that it produced at the site
Zero net energy building in the site	The amount of provided energy by the renewable energy resources is equal with the consumed energy of the building
Zero net energy building out of site	Similar to zero net energy building in the site; but energy purchase from outside is completely from renewable energy resources
Zero net resource/main energy building (ZEB resource)	The time calculated for a resource, is the amount of energy used in a year. For electricity, only 35% of the required energy in the fossil power plants in converted to useful energy. For calculation of the total energy resource of the building, the conversion coefficients of region to resource will be used
Zero net energy cost building (ZEB cost)	The cost of energy is equal with the income from selling the electricity to the network
Zero energy emission building, zero carbon energy, zero emission energy	The emission of carbon due to application of fossil fuels is equal with the amount of renewable energy production at the site

Table 1: terms and definitions of ZEB and ZCB

In regional level, these factors include climate region, type and usage of the building and accessibility to reasonable energy or technology products in the local market. However, the most common pattern is in a way that the main portion of energy is consumed in operational and constructional phases. In countries of Economic Co-operation and Development (OECD), based on the report of 200, building sector uses 25-45% of final energy consumption (OECD, 2003). In Asia, based on the reports of 2006, building sector uses 40-50% of final energy consumption(IEEJ, 2006). For example, the main part of energy is used for heating the rooms, internal conditioning, lightening,heating the water, mechanical conditioning systems and running home and administrative appliances. In addition, it is anticipated that due to the population growth and urbanism, especially in developing countries of Asia, energy consumption of this section raises rapidly in future (Wen, *et al.,* 2007). Along with energy consumption issue,environmental challenges of construction are also important among which a) application of huge part of natural resources (land, materials and water) b) production of huge amount of waste water and solid waste materials and c) emission of pollutant can be mentioned (UNEP, 2007)(OECD, 2003).

Green buildings have been considered as a solution for management of environmental performance of the buildings (Adshead, 2011)(Cole 1998). While legislations abut energy efficiency of the buildings and equipment are known as the main tools of policy makings to reduce the energy consumption of the buildings (Lautsen, 2008)(UNEP, 2007).

Green building trend

From early 90s, green building construction have started as the main solution for enhancement of energy efficiency in the buildings and resolving the environmental challenges of buildings. In contrary to conventional buildings, green buildings should be designed, constructed and applied with the aim of minimizing the effects of artificial environment on the natural ones. Regarding the qualitative criteria of green buildings, Dowden and Theron (2011) interpreted the green buildings as the trend of creating buildings by application of processes committed to environmental issues throughout the life of building from construction site locating to design, construction, application, maintenance, reconstruction and deconstruction. Characteristics of green buildings should be measurable and provable in relation to interaction with the environment. Rating systems of green buildings which were established by governmental or non-governmental organizations, can be helpful in measuring and justifying the green buildings via environmental evaluations and confirmation processes. The most common criteria series for rating the green buildings includes following items: sustainability in development of building position, optimal application of land, energy, water and material; environmental loading and internal air quality and environment. Some rating systems may consider the transportation, cultural and innovation aspects in the building design (Emmanuel and Baker, 2012). Green building rating systems also help the owners and experts in reaching to environmental performance of the building and reducing the energy consumption and costs (Cole, 1998). Moreover, one of the main characteristics of a green building is more efficient use of energy; otherwise they can't be called green buildings. Nowadays, governmental support for creating green buildings is increasing. In Britain, although environmental evaluation of BREEAM is not mandatory in national level, but the local authorities expect that building development reaches to specific rates of BREEAM as a part of design requirements and all the new state buildings should attain BREEAM excellent rate (Adshead, 2011)(BREEAM, 2014). In Asia, green building rating system of Taiwan called EEWH has been mandatory for private and public buildings from 2001. Chen and Chen 2001 in Hong Kong rating system of BEAN PLUS is arbitrary, but all the new public buildings larger than 10000 m2 should at least gain the Gold grade from BEAM PLUS (Hkg press Release, 2009). Although according to Murphy 2011, in most European countries is the main trend in construction industry especially in those which are present in construction market, but without the proper policy of the government, improvement of energy consumption in the buildings and development of green buildings will be slow.

Carbon effects evaluation

In fact, carbon is used for brief expression of carbon dioxide (CO2) or carbon dioxide equivalent (CO2-e) which includes both CO2 and also other gases capable of global warming (GWP). An "effect" is in fact a qualitative measurement indicating natural resources allocation to human. This measure determines how human activities can impact the global sustainability (Cucek, *et al* ., 2012).

Carbon effect is a measurement of direct (in site, internal) and indirect (out of site, hidden, external, up and down stream) emission of CO2 of an activity or during the life cycle of a product which can be assessed in mass unit. Process-oriented carbon effect analysis during life cycle is an analytical tool focused on sensitive and inefficient points on life cycle and provides a framework for optimization and trade off (Hernandez, Kenny, 2010).

Carbon effect of buildings

Carbon effect of a building is total amount of CO2 and other GHGs emitted during life cycle of the building expressed in CO2 kg equivalent CO2 (kg CO2-e). This includes all GHGs produced during raw materials construction, materials transportation, constructional operation, periodical reconstruction and materials replacement and discharge of building materials at the end of life cycle. Figure 3 shows carbon effect of a building and its components. The majority of carbon emission of buildings is due to indirect resources, in the other words, it is the fuel consumed for electricity generation. Therefore, the most effective way to reduce the carbon effect is to decrease the energy required for generation or decrease the dependence to carbon-emitting fuels (Brown, 2010).

Legal management of energy consumption in buildings

Global development of construction is traditionally under the influence of legal management; therefore it is anticipated that construction-related laws can be crucial tool in presenting a criterion or framework for enhancement of energy efficiency or reduction of energy consumption in the buildings. Legislations for such purposes started in 60s. In 1961, Denmark introduced thermal insulation requirement for the buildings to limit thermal energy dissipation (Engberg, 2012). Sweden, USA and Britain also used the same regulation for the houses in 70s. In Asia, Singapore and Japan introduced energy efficiency laws for commercial buildings (Wen, 2007). European countries, instead of focusing on buildings cover, also made minimum energy efficiency standards for home appliances mandatory. For example, France and Russia introduced mandatory energy efficiency standards for refrigerators in 1966 and 1976, respectively. However, these laws had small impact on energy consumption due to weak implementation (Waide, *et al.,* 1997). In USA, energy consumption program for consumption products under energy legislation and protective laws of 1975, enabled the central state to control the energy efficiency of main equipment such as refrigerators, freezers, washing machines, dry laundering, air conditioning and heat pumps. California state was the pioneering state in this regard and managed to introduce a mandatory rating system in 1978 (Miller ,1997)(Turiel, 1997). By increase of concerns on climate change from 89s, several publications such as 4 reports of UN intra-governmental board in relation with climate change in 90s have drawn considerable attention. These reports stated that combustion of fossil fuel will produce huge amount of carbon dioxide which will finally enter the atmosphere and affect the global climate. Therefore, all the governments try to stabilize carbon emission under international treaties such as Kyoto protocol. The taken measures include extension of energy efficiency laws to include more equipment and installation such as elevators; and application of more extended policies instead of legislations such as voluntarily, financial and economic programs to encourage the shareholders to participate in improvement of buildings energy (Vorsatz, *et al.,* 2007). One of the effective policies of EU was implementation of energy performance of buildings directive (EPBD) in 206. 2002/91/EC obliges the EU members to implement a) energy efficiency calculation based on article 3 of EPBD; b) minimum energy efficiency standards for under construction buildings, those are being sold or rented according to article 7 of EPBD. (EU commission, 2003). According to article 9 of 2010/31/EU, EPBD, governments have to I) guarantees that all the new buildings will reach to zero energy consumption (NZEB) until December 31, 2020 and the buildings owned by social authorities will reach to NZEB until 31 December 2018 and ii) program some national plans to increase the number of NZEB (EU- commission ,2010). Under the influence of EPBD, the focus of legal policies has changed from energy efficiency of the buildings to energy classification or confirmation systems for buildings with low energy and carbon which are those using renewable energy (Kibert and Ford, 2012)(Liu, 2011).

Policies for low carbon buildings, artificial environments and spatial planning

Legal monitoring of energy efficiency in the buildings and hoe appliances are originated from the concerns about the energy resources and high cost of fossil fuels. These concerns have remained, although in building monitoring systems, the options for enhancing the energy performance of the buildings are limited. Examples of this field are improvement of thermal properties and insulation of component, enhancement of thermal standards, determination of minimum standards for fixed electrical installations, improving the design of heating and cooling system and installing integrated photovoltaic installations (Levine, *et al.,* 2007). However, numerous issues hinder macro-improvement of energy efficiency in the buildings some of them are: High investment costs for energy-conserving equipment; traditional methods of construction; defected plans presented to the owners; multi-step processes of design and construction. UN persists that for achieving to higher energy efficiency in buildings and cities, integration of spatial planning with policies is required. for example, while energy efficiency improvement is desirable; this issue is also necessary to guarantees the residents' access to an efficient system of public transportation. Therefore, energy efficiency improvement in the buildings should not be limited to building monitoring. Study of V and Brown 2010 showed that urban eras increase GHG emission from 5 main sections i.e. buildings, industry, transport, wastewater and agriculture. Building has the highest electricity consumption and carbon gas emission of the cities. In addition to technology, energy efficiency improvement in buildings can be enhanced by spatial planning elements such as a) spatial aspects of building development such as position, location, appearance of the building and b) the relationship between the building and its surrounding area and c) implementing the desired urban development pattern. For spatial aspects of the buildings, most rating systems of green buildings include some criteria for the designers. In this regard, implementation of green buildings should be along with government policies. One of the successful examples of these policies was in USA where the buildings in New York, Philadelphia, Huston and San Francisco were obliged to reach to a specific level of leadership in energy and environmental design (LEED) management system.

Shannon et al 2008 conducted a research and proposed that providing green environments and adequate open spaces in the artificial environments not only enhance the energy efficiency of the buildings, but also can be helpful in community health. Successful examples were implemented in Hong Cong public residential lands. In accordance with such approach (Policy Address, 2009-2010) by senior executive manager HKSAR targeted following goals: a) all the new buildings should at least have 20% green space; b) low-floor public buildings will be constructed with green roofs and c) buildings with green walls can be provided for public buildings if possible. Decisions on land use and urban structures can help in providing long-term benefits for energy efficiency of buildings and artificial environments, for example creation of a surface of residential concentration for specific areas, proper public transport and cost-effective infrastructures in terms of energy consumption. One of the successful examples of creating cost-effective infrastructures was trial project of Hong Kong for wider application of cold water air conditioning from 2000. This is a central cooling system providing cold water for non-residential buildings air conditioning systems. Central cooling unit provides cold water and this water would be transmitted by a network of underground water to the buildings. Investigation of this trial project in 2008 showed that increasing trend can be observed in energy storage and related applications. This project was welcomed by developers, owners and financial managers. Therefore, this trial project was converted to a fixed one in June 1 2008, and renamed to sweet water cooling towers for air conditioning. Until April 2009, 394 applications were accepted which included 86 covered private regions and 74 million of non-local GFA in Hong Kong. Urban areas have high potential for artificial environments. For supporting low energy or carbon buildings and artificial environments, spatial planning should include following principles.

Comprehensive governmental management and commitment

Government commitment and management can be established by declaration of national policies for goals of energy consumption and GHG emission. These goals should be able to resist against the challenges imposed by shareholders. In Britain, statements 1 and 22 of program revealed that local authorities have to a) develop policies to reduce climate change and b) present instructions to implement low-carbon technologies. By these statements, planning system can be used for reinforcement of renewable energy consuming equipment. Under programming policies, development of buildings with area larger than 1000 m2 or 10 units requires accepting the goals of renewable energy during program development and reaching to these goals until the complementation of the building. Until 2007, 113 building development programs out of 350 programs managed to save 135 Ktons CO_2/year and reached to the predicted saving in the building programs

Coordination with policies and national legislations

This coordination can be achieved by proper relationship between building legislations and national energy policies such as license presentation according to environmental standards, certificates and implementation measures. In Singapore, strategies of sustainable artificial environments were integrated with national energy policies, programs and building legislations. For instance, to minimize misusage, government do not give subsides to all. Instead, supports more market competition of distributed commercial centers to reduce the need for transportation and therefore, reducing the traffic at peak hours; also, guarantees high degree of green sign as a condition for land sell to create new buildings in the strategic fields.

Cooperation with shareholders

This can be done by maximizing shareholders participation, public Contemplation, close collaboration with social groups and local representatives to reach to specific solutions for each region. In 1997, California was the first state which developed mandatory building standards for reducing energy consumption in the buildings. According to the law, building permissions would not be issued for the new buildings until their complete compliance with the laws. Severe opposition of building construction industry with the laws and compliance with the mandatory standards were reported to be low. In spite of oppositions of this industry, California was not successful in reinforcement of the legislations and gradually replaced the law by education on use of clean energy to the designers, constructors and authorities to enhance the energy efficiency of the buildings. Therefore, successful promotion of a mandatory project depends on a public Contemplation process to guarantee support and helping the industry to modify the project into an acceptable level.

Balance between mandatory and voluntarily approaches:

There are successful examples of implementing energy efficiency measures in buildings. Taiwan started a voluntarily approach to reduce carbon emission form buildings which then converted to a mandatory approach. In Britain and Netherlands, a mandatory approach is used alongside the legislations (Adshead, 2011). Although Rui 2011 persisted that developing countries like China need strong legislation, but risk of economic penalties in reaching to these results showed that the main obstacle on the path of green building promotion in developing countries depends on organizational laws and the costs of public inform. Mandatory conditions can be potentially more harmful than the voluntarily ones.

CONCLUSION

Many countries all around the world are developing zero carbon or low carbon buildings to reduce GHG emission and raise the environmental awareness. ZCB.ZEB can result in transmission to low-carbon communities. In near future, ZCB and low carbon buildings will be the main issue of the urban developers. By investigation of ZCB/ZEB measures and logic of carbon effect as the indices for measuring the stability, it is possible to enhance our understanding about the zero carbon designing during life cycle.

It must be mentioned that market need for ZCB/ZEB is still limited. By development of integrated and multi-disciplinary ZCB and considering social and economic considerations during the decision making process, it is hoped to develop an effective strategy to decrease GHG emission and fight with climate change. Moreover, government support has globally increased energy efficiency of the buildings, this can go back to 70s and discussion on climate change and concerns about energy costs and security. Most of policies for improvement of energy efficiency are focused on buildings quality instead of buildings interaction with their surrounding environment. Urban areas have high potential for buildings and residential areas energy efficiency. Spatial planning can also play an important role in guiding the building sector to use lower amount of carbon. To achieve to a successful implementation of the energy policies, these policies have to possess spatial planning elements along with management and commitment of the government, proper coordination with national policies and laws, proper participation of the shareholders and adequate balance between mandatory and voluntarily approaches.

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