Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 12	No. 4	pp. 625-629	2013

Original Research Paper

Impact Analysis on the Energy-Saving and Land-Saving Properties of Green Buildings with Different Per Capita Floor Space of Residential Buildings

He Yueer, Peng Shini and Liu Meng
Key Laboratory of the Three Gorges Reservoir Region's Eco-environment (Chongqing University), Ministry of Education, Chongqing 400045, China
Faculty of Urban Construction and Environmental Engineering, Chongqing University, Chongqing 400045, China

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 5-8-2013
Accepted: 10-9-2013

Key Words:
Green building
Per capita floor space
Land conservation
Energy conservation

ABSTRACT

China has published "Green Building Action Plan". Developing green building is necessary to shift urbanization mode in China. "China Evaluation Standard for Green Building" has set per capita residential land index as the prerequisite for residential buildings. Absolutely, per capita residential land index depends deeply on per capita floor space of residential building. In China, national and local "Evaluation Standard for Green Building" raise demands of per capita residential land index. According to those requirements, this paper conducted a case study and calculated changes of residential construction land area with different set values of per capita floor space of residential building. This paper also built a residential building model and utilized simulation to analyse annual building energy consumption. Results indicate that per capita floor space of residential building decreases accordingly while per capita residential land index reduces, and every 5% increase in per capita residential land index translates into about 7 percent decrease in construction land area. On the aspect of energy consumption, per capita floor space of residential building reduces 17.2% only. While annual energy consumption reduces 17.45% in return. It is concluded that controlling per capita floor space of residential building is important to maintain the energy-saving and land-saving properties of green building.

INTRODUCTION

Global climate change seriously affects human existence and development (Hu 2009, Du et al. 2012, Wei & Hu 2013). China, as a responsible great power, has promised to decrease carbon dioxide emissions per unit of GDP by 40% ~ 45% in 2020 (Wen 2009). According to the report of IPCC, green buildings have the potential to reduce the expected baseline emission by 29% on the aspects of residential and commercial buildings (United Nations Ratio 2008). The development of green buildings is the key to realize sustainable buildings development, implement emission reduction target and cope up with the climate change.

According to "Evaluation standard for green building" GB/T50378-2006, green building shall use resources as few as it can, provide health, applicable and efficient space for people and keep a harmonious coexistence with the environment. Energy-saving and recourse-saving are core contents of green buildings.

Per capita residential land index is a key indicator to control residential buildings land saving (Chongqing Evaluation Standard for Green Building DBJ/T50-066, 2009). Article 4.1.3 of "China Evaluation standard for green building GB50378" sets the upper limit of per capita residential land for all kinds of residential buildings, 43m^2 for low-rise buildings, 28m^2 for multistorey buildings, 24m^2 for medium-high level buildings, and 15m^2 for high-rise buildings. Per capita residential land means that how large construction land area each resident will own. This index is as germane as community development intensity and housing design (Ye & Li 2012). From formulas 1.1-1.3, it is obvious that per capita residential land, per capita floor space of residential building and construction land are highly interdependent. So, in the same plot ratio, control per capita floor space of residential building is a powerful measure to control per capita residential land (Chongqing Evaluation Standard for Green Building DBJ/T50-066 2009).

Per capita residential land (Chongqing Evaluation Standard for Green Building DBJ/T50-066 2009) = residential construction land area/the number of resident ...(1.1)

Per capita floor space of residential building (National Bureau of Statistics of China 1994-2012) = floor space of residential building/the number of residents ...(1.2)

Building density = (the whole projective area/residential construction land area) × 100% ...(1.3)

However, per capita floor space of residential building reflects urban resident living condition at some level (An 1994). Per capita floor space of residential building has grown fast in the phase of social-economic booming. Large

houses and villas have been on increasing growth (Fig. 1). In this trend, the situation of per capita residential land is not going well (Fig. 2). It is contrary to the purposes and principles of green building.

In some case, it will meet the requirements of "green building" if the project as a whole by matching high-density high-rise buildings. But, if such parts of a project applied for green building evaluation alone, they would not be able to fit the bill. Therefore, this problem is causing quite a bit of controversy (An 1994). However, controlling per capita residential land by controlling per capita floor space of residential building is important to maintain the land-saving property of green building.

On the other hand, controlling per capita floor space of residential building is crucial to maintain the energy-saving property of green building as well. Presently, China's total energy consumption of the whole society has accounted for 20.3% of the total energy consumption in the world (China Petroleum and Chemical Industry Association web). At the same time, the consumption structure of Chinese urban and rural residents is upgraded gradually from "clothing, food" to "shelter, transportation" and life style changes from survival to comfort. Their requirements of the living conditions about floor space of residential building, indoor environmental comfort and so on are improving gradually. As a result, building energy consumption and resource consumption continue to rise, which will be the main elongated point of energy consumption and CO_2 emissions for the next 20 years.

Research on main factors that influence residential buildings energy consumption has been carried out, both in domestic and abroad. Results indicate that per capita floor space of residential building is one of the main factors influencing residential building energy consumption (Li 2011, China Petroleum and Chemical Industry Association web, Pu et al. 2012). Above all, this paper does the research to analyse the impact of construction land area and building energy consumption with different per capita floor space of residential building.

LAND CONSERVATION

As China's urbanization progress and the economic mode of high investment type in the current situation, land and energy resources and eco-environment are overwhelmed. Relevant data concluded that every 1% increase in China urbanization rate translates into a 1004 square kilometres increase in construction land area. Land resources shortage is a huge challenge faced by the urbanization process. Presently, land conservation has been the key content of "green building". Regulations on land conservation based on

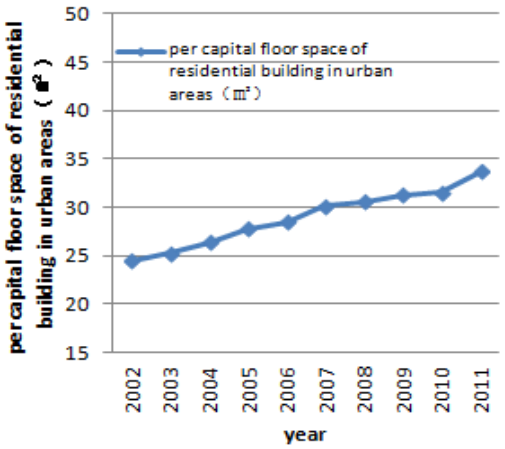

Fig. 1: Per capital floor space of residential building in urban areas (National Bureau of Statistics of China, 1994-2012).

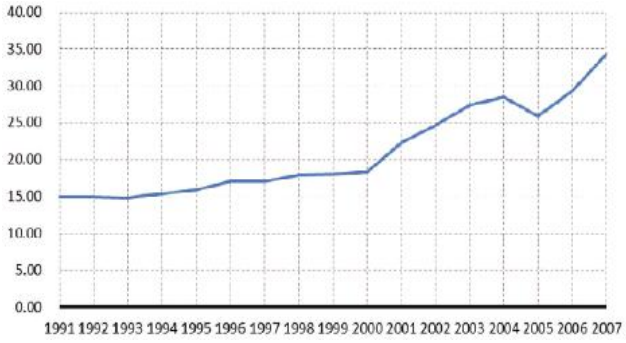

Fig. 2: Changes of per capita residential land (Li 2011).

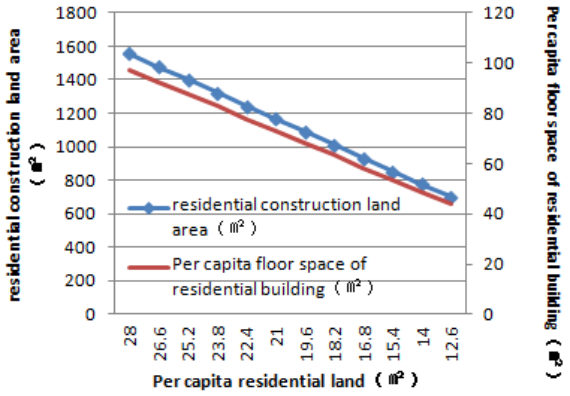

Fig. 3: Changes of per capita floor space of residential building and residential construction land area along with per capita residential land index.

BREEAM-Communities, LEED-ND and China Evaluation standard for green building are summarized in Table 1.

How will the size of per capita floor space of residential

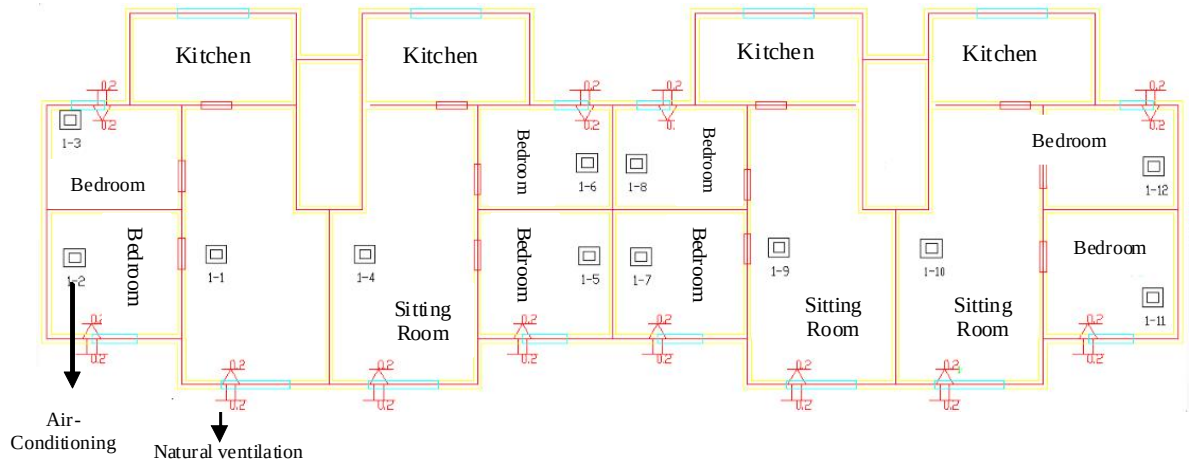

Fig. 4. Floor plan for sample buildings.

building impact on construction land area? A case study was conducted in this article to analyse the impact on land conservation. The 5-layer typical plate structural building in Chongqing was chosen as an example. Each layer of the building consists of four same flats. Upper limit of multistorey dwelling density is 25% with Article 4.1.4 in "Chongqing Evaluation Standard for Green Building DBJ/T50-066". As a consequence, sample building density was set as 25%. And average family household size (person/household) is 2.78 (National Bureau of Statistics of China, 1994-2012).

According to Article 4.1.4 in "Chongqing Evaluation Standard for Green Building DBJ/T50-066", upper limit of per capita residential land for multistorey dwelling is 28m^2. In order to analyse the impact on residential construction land area made by per capita floor space of residential building, the way that taking every 1% decrease in per capita residential land as an example and translate in per capita floor space of residential building was used. Relevant data are shown in Fig. 3.

To clarify, according to "Design code for residential building GB50096", the lower boundary of residential usable floor area corresponds to per capita residential land index under these suppositions is 12 square meter. So, 12.6 square meter per capita residential land is the last calculation in Fig. 3.

In summary, per capita floor space of residential building reduces along with decreasing of per capita residential land index. In this case, every 5% increase in per capita residential land index translates into about 7 percent decrease in construction land area. For example, if per capita residential land index changed from 28m^2 to 21m^2, construction land area would reduce to 1167.6 m^2 from 1556.8 m^2. The fall is about 25%. It is easy to see the importance of controlling per capita floor space of residential building for realizing green building.

ENERGY CONSERVATION

Research on main factors that influence residential buildings energy consumption has been carried out, both in domestic and abroad. Results indicate that per capita floor space of residential building is one of main factors influencing residential building energy consumption (Pu et al. 2012, Tuan & Lefevre 1996, Wang & Liu 2005, Chen 2008). Energy consuming in dwelling building occupies quite a few proportion in total energy consumption. Building energy consumption grows constantly in China with the increase of urbanization rate, development of economics, people's income and continuous improvement of the living standard. The total merchandise energy consumption of building experienced a 1.3-fold increase from 7.12 ×1015kJ in 1996 to 16.50 × 1015kJ in 2006. The energy consumption of urban residential commodity was 7.97 × 1015kJ, accounting for 44% of total building energy consumption in 2006. It shows how large proportion of residential building energy consumption makes up in the final energy consumption of the whole society (Pu et al. 2012).

The level of residential buildings consumption depends on many factors with time-varying, complexity, randomness, regional characteristic, etc. (Pu et al. 2012). In order to analyse the impact on residential building energy consumption with different per capita floor space of residential building, this article selects two 5-layer typical plate structure residential building located in Chongqing for comparative analysis (energy consumption mainly involves heating, air conditioning, lighting, equipment, domestic hot water and cooking). Each layer of the two buildings consists of four same flats. The unique difference of the two buildings is per capita

Table 1: Regulations on land conservation.

Index system Articles	BREEAM-Communities	LEED-ND	China Evaluation Standard for Green Building
Land conservation	Reuse of land	Smart Location Agricultural Land Conservation Brownfields Redevelopment	Propose per capita residential land index (Article 4.1.3)

Table 2: Associated parameters about sample buildings.

No.	Building density (%)	Residential construction land area (m^2)	Average family floor space of residential building (m^2/ household)	Per capita floor space of residential building(m^2/per capita)	Per capita residential land (m^2/per capita)
1	25	1445	90.35	32.5	26
2	25	1205	74.78	26.9	21.67

Table 3: Each part energy consumption of sample buildings.

No.	Energy consumption						Annual energy consumption (tce)
	Heating (kwh)	Air conditioning (kwh)	Lighting (kwh)	Equipment (kwh)	domestic hot water (m^3/a)	Cooking (m^3/a)	
1	12384	23964	17610	40616	2160	1440	15.99
2	11077	18440	14536	33689	1800	1200	13.20

Table 4: Baseline values of building energy consumption in some countries (Long et al. 2011).

The type of building	Baseline values of building energy consumption (kWh/(m^2·a))			
	UK	USA	Germany (Level D)	Sweden (Class I)
Residentialbuildings	228	138	200	150

floor space of residential building (Fig. 4).

Based on Article 4.1.4 and 4.1.20 of "Chongqing Evaluation Standard for Green Building DBJ/T50-066", "Cord for Design of Civil Buildings GB50352" and "Design Code for Residential Building GB50096", associated parameters about two buildings are given in Table 2.

This paper uses Dest-h to analyse residential building annual energy consumption. Parameter settings, such as thermal performance of building envelope, internal disturbance index, HVAC, etc. meet requirements of "Chongqing Evaluation Standard for Green Building DBJ/T50-066" and "Design Standard for Energy Efficiency 65% of residential building DBJ50-071".

Heating and air conditioning energy consumption are obtained through simulation. Taking rooms of different functions into consideration, lighting and equipment work-rest schedules and average power values per square meter are different. Lighting and equipment energy consumption can be calculated by set values in simulation. Meanwhile, natural gas consumption for domestic hot water is 1.2 $m^3/(m^2.a)$, and natural gas consumption for cooking is 0.8 $m^3/(m^2.a)$ (Liu & Fu 2008). To unify energy consumption unit, per cubic meter of natural gas is converted to 1.2143 kilograms of standard coal, and kilowatt-hours is converted to 0.1229 kilograms of standard coal (National Bureau of Statistics of China, 1994-2012). Above all, each part energy consumption of sample buildings is given in Table 3.

Compared to sample building 1, per capita floor space of sample building 2 reduces 17.2% only. While annual energy consumption of sample building 2 reduces 17.45% in return. It is easy to see that energy consumption of savings can meet annual energy demand of heating and cooking of building 2.

Building 2 shall save 2.79 tons of standard coal during the whole year. How much benefits it will bring? Some countries have set baseline values of building energy consumption so far, such as UK, USA, Germany, etc. Baseline values come from building energy consumption survey statistics. Relevant departments will update baseline values on the basis of new data. The latest data for residential buildings are given in Table 4.

According Table 4, if 2.79 tons of standard coal saved

by Building 2 during the whole year were used in UK, it would meet the annual energy requirements of a house whose floor area is 99.8 square meters. If in USA, the house's floor area would be 164.9 square meters. In Germany, it is 113.8 square meters, and 151.7 square meters it is in Sweden.

CONCLUSIONS

According to requirements of National and Local Evaluation Standard for Green Building, this paper conducted a case study and simulation analysis. Results indicated that controlling per capita floor space of residential building is important to realize the energy-saving and land-saving properties of green building:

1. Based on the case study, per capita floor space of residential building decreases accordingly, while per capita residential land index reduces, and every 5% increase in per capita residential land index translates into about 7 percent decrease in construction land area. For example, if per capita residential land index changed from 28m^2 to 21m^2, construction land area would reduce to 1167.6m^2 from 1556.8m^2. The fall is about 25%.
2. In this case, per capita floor space of residential building reduces 17.2% only. While annual energy consumption reduces 17.45% in return.

In a building, not only does per capita floor space of residential building influence per capita residential land index, but plot ratio, the whole projective area of building, storeys, etc. as well. However, results of this paper show that controlling per capita floor space of residential building is a strong measure to reduce construction land area and building energy consumption.

ACKNOWLEDGEMENT

The paper is supported by the special fund of Chongqing Key Laboratory (CSTC). The authors would like to acknowledge the help of Professor Ding Yong (Faculty of Urban Construction and Environmental Engineering, Chongqing University).

REFERENCES

An Shoujun 1994. Question per-captita living space, Chinese Real Estate, 162: 59.

Chen Shuqin 2008. Analysis on characteristics of energy consumption of city residential buildings and energy saving evaluation based on statistics theory. Dissertation of Hunan University, Hunan, pp.1-4, 17-30.

China Petroleum and Chemical Industry Association web, http://www.ciesc.cn/asp/home/newsdisplay.asp?id=345

Chongqing Evaluation Standard for Green Building DBJ/T50-066, Chongqing, 2009.

Du Zhenyu, Jia Lei and Xue Didi 2012. Numerical analysis of thermal environment in a natural ventilation sunlight greenhouse. Theoretical and Applied Information Technology, 45(2): 448-455.

Hu Jintao 2009. Join Hands to Address Climate Challenge. At the Opening Plenary Session of The United Nations Summit on Climate Change.

Li Xinyang 2011. Research on per capita residential land index. In: Proceedings of Transformation and Reconstruction, pp. 6582.

Liu Gang and Fu Xiangzhao 2008. Study on Shenzhen Design Standard for Energy Efficiency 65% of Residential Building. Master Dissertation of Chongqing University, Chongqing.

Long, Weiding and Bai wei 2011. Community Energy Planning for Built Environment in Low Carbon Cities. China Architecture & Building Press, China.

National Bureau of Statistics of China 1994-2012. China Statistical Yearbook, China Statistics Press, Beijing.

Pu Qingping, Li Baizhan and Yu Wei 2012. Energy consumption forecast model of urban residential buildings in Chongqing. Central South University (Science and Technology), 43(4): 1551-1556.

Tuan, N.A. and Lefevre, T. 1996. Analysis of household energy demand in Vietnam. Energy Policy, 24(12): 1089-1099.

United Nations Ratio 2008. Green Building is the Direction of Future. UNO.

Wang, Yi and Liu, Jia-ping 2005. Investigation on residential building indoor environment in Xi'an and usage of air conditioners. HVAC, 35(12): 4446.

Wei, Fulei and Hu, Caimei 2013. Empirical analysis of regional energy consumptions and economic growth. Theoretical and Applied Information Technology, 48(1): 311-318.

Wen, Jiabao 2009. Build Consensus and Strengthen Cooperation to Advance the Historical Process of Combating Climate Chang. Address at the Copenhagen Climate Change Summit.

Ye, Ling and Li Xun 2012. Index performance on land use and planning of dwelling projects with green building label. Special article of ECGB, ECGB, pp. 26-29.