Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268 | Vol. 13 | No. 1 | pp. 203-210 | 2014

Original Research Paper

Decomposition Analysis of Driving Factors for Building Energy Consumption in China

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 23-12-2013
Accepted: 29-1-2014

Key Words:
Building energy efficiency
Decomposition analysis
Energy saving
LMDI

ABSTRACT

This paper offers a model for analyzing the factors affecting building energy consumption based on qualitative analysis. Logarithmic Mean Divisia Index (LMDI) method is used to decompose the driving factors causing China's building energy consumption change during 2005-2009. It is concluded that improvement of people's living condition and the increment of building area significantly lead to increase of energy consumption. Although the effect is relatively small, population and urbanization devote to energy consumption as well, while improvement of building efficiency is slow for the growth of energy consumption. From year 2005 to year 2009, energy saving of 121 million tons of standard coal, has been achieved by improving building energy efficiency. It decreases building energy consumption by 23%. Building energy efficiency played an important role in protecting the environment.

INTRODUCTION

Following China's continuous development of industrialization and urbanization, the environment and resources have been challenged by the increasing energy demand. Continued growth in energy consumption is considered to be one of the main causes of frequent haze in China, reducing fossil fuel consumption and promoting clean energy is an important measure to control air pollution. Developing a sustainable energy consumption strategy is an essential part to achieve sustainability of China's socio-economic and environmental development.

Decomposition analysis on driving factors of energy consumption or CO_2 emission is a hot topic in the area of energy related research. As a widely accepted methodology, Index decomposition analysis is used to solve energy and environmental problems. The principle of this decomposition analysis is to express the target (such as energy consumption or carbon emissions) as a product of several factors, and to calculate the devote value explained by each corresponding observed change. To investigate the driving factors of energy consumption and carbon emission in China, considerable work has been conducted based on decomposition analysis.

Zhang examined the whole energy consumption of China industry (1990-1997) by adopting Laspeyres entire decomposition analysis. It is concluded that industry energy consumption is affected by scale effect, actual strengthen effect and structural effect. Actual strengthen effect is revealed as the main factor (Zhang 2003). Logarithmic Mean Divisia Index (LMDI) is used by Wang et al. (2005) to analyze the CO_2 emission in China from year 1957 to 2000. They reported that energy intensity, as a technique factor, is the key factor of minimizing carbon emission. Factor analysis has been conducted by Liu et al. (2007) to analyze the CO_2 emission change produced by China industry energy consumption during year 1998-2005 by employing LMDI method. It is stated that instead of emission coefficient, energy resource category, and industry structure, energy intensity has considerable contribution to CO_2 emission decreasing. Furthermore, Ying Fan et al. (2007) used Adaptive Weighting Divisia (AWD) method to calculate the CO_2 emission intensity subject to energy consumption from raw material manufacturing process in China during year.

From the literature review, it is found that most studies conduct decomposition analysis on driving factors with fixing their research scope on total national energy consumption amount and industry energy consumption. Few studies focus on the driving factors of building energy consumption although building is an important sector of energy consumption as well as associate green house gas emission. It is reported by UNEP-SBCI that building sector has consumed 40% of the global energy and produced 1/3 of the GHG emission (UNEP-SBCI 2010). Building energy consumption is affected by building characters, urbanization rate, gross floor area, and residents' behavior of energy utilization. This is different from the energy consumption of manufacture industry which is affected by economic growth, industry structure, energy consumption per unit output value, etc. In this paper, the factors influencing energy consumption of building in China have been discovered from prospects of both theoretical and practical. A decomposition analysis model is established to calculate the influence by those driving factors. As a theoretical reference, a series of recommendations have been provided to assist the government to make rational policy to encourage building industry to minimize energy consumption and carbon emission.

DRIVING FACTORS OF DECREASE OF BUILDING ENERGY CONSUMPTION

Many factors affect energy consumption of buildings. Those factors could be categorized as population (amount of population, urbanization rate, age distribution), economic growth (GDP and total productivity of building industry), the level of urban development (residential area, gas utilize rate, centralized heat supply rate), people living condition (average residential area per person, average incoming, and resident consumption). In this study, in order to describe the impact on building energy consumption by each factor, the driving factors of energy consumption change of buildings are divided into five categories: population, urbanization, national construction scale, residents' behavior and building energy efficiency.

Population: Human activity is regarded as a main cause of environmental change. Since 1750, global atmospheric CO_2, methane (CH_4) and nitric oxide (N_2O) concentration have increased significantly due to human activities (IPCC 2007), which is far beyond the value measured based on ice core records for thousands of years in pre-industrial age. China is the world's largest populous country. In 2010, the total population of China is 1.34 billion, which is about one-fifth of the world's population. It is predicted that China's population will reach the peak of 1.5 billion in 2030 (National Population Development Strategy Research Group 2007). This means that in the current and next decade, China's population will keep growing with average annual increasing rate of 8-10 million. Increase in the total population is bound to bring increased energy demand, and lead to an increase in greenhouse gas emissions. York et al. (2003 stated that the elasticity coefficient of population to carbon dioxide emissions is close to 1.

Urbanization: Urbanization is an inevitable stage of human civilization and economic and social development. Referring to the urbanization process experienced by many developed countries, urbanization is in an acceleration stage when urbanization rate reached 30%. In 1996, China's urbanization rate is 30.48%. It remained growth with an increasing rate of 1.44 % during the following 8 years. China's urbanization rate is reported as 46.59% in 2009. It will reach about 50% in year 2015 and more than 70% in year 2050 with assumption of the average urbanization rate annually increasing by 0.7%. China's urbanization process will be initially completed when urbanization rate is 70%. Energy consumption for living by urban residents is higher than in rural areas. In 2009, the value of energy consumption per person by urban residents is 330 kilograms of standard coal, which is 1.8 times of 185 kilograms of standard coal consumed by rural residents. With the further boost of urbanization, a large number of rural residents will turn into urban residents, which will lead to a significant increase in building energy consumption.

National construction scale: China is the world's largest urban construction place. In the past three years, new buildings with total gross floor area (GFA) of more than 20 billion square meters have been constructed each year. The total amount of GFA of new buildings is 15.7 million square meters from 2000 to 2009, accounting for nearly 40% of the total GFA of existing buildings. In other words, 40% of existing buildings are built after the year 2000. From technical view, increasing GFA of a building leads to increment of the operational load of energy-based facilities. For instance, the loads of lighting system, heating and air-conditioning are designed based on GFA. Buildings with larger GFA request greater energy load. Taking heating as an example, the average energy consumption for heating of China's northern urban area is 20kg standard coal per square meter each year. This means that each increase of 1 square meter of GFA, the annual heating energy consumption will increase by 20kg of standard coal. Therefore, increase in building GFA is a direct factor of building energy consumption growth.

Residents' behavior: Residents' behavior of energy usage has a great impact on building energy consumption. In China, with such a large population, the cumulative effect of this impact is especially huge. Residents' behavior of energy usage is mainly influenced by three factors: income levels, energy prices and environmental awareness. In general, people with higher income may require more comfortable living condition, which usually cause higher energy demand. Energy price is inversely proportional to energy demand. Energy demand will be reduced if energy prices increase. With environmental awareness, people initially have conscious awareness of energy conservation. Overall, as living condition improve, residents' behavior of energy use leads to increment of building energy consumption.

Building energy efficiency: Energy efficiency is the main driving factor of improvement of building energy conservation, which include the thermal performance of building and energy efficiency of energy-based devices. Under a dual influence of advanced technological improvement and energy conservation related policies, China has greatly enhanced energy efficiency in buildings. The percentage of building energy saving required by standards is upgraded from 30% in 1980s to 50% in 2010s, and 65% is set as a trial point in several cities. Furthermore, energy efficiency of household appliances is annually increased. Air-conditioning, for example, in 2010 China introduced a new energy efficiency grade system which classifies the energy efficiency for AC into 3 grades instead of 5 grades described in the old system. In this new system, grade 3 equivalents to the grade 2 of the original system. Those AC declared as grade 2, 3 and 5 in the original system were banned being produced.

DECOMPOSITION MODEL OF DRIVING FACTORS OF CHINA BUILDING ENERGY CONSUMPTION

Model development: Building energy consumption could be divided into 4 categories by usage: energy consumption of rural residential buildings, energy consumption of urban residential buildings, and energy consumption of urban public buildings. The formula, I = PAT, is applied in this paper. The energy consumption of rural residential buildings is expressed as:

$$E1 = P*U1*\frac{RGFA}{P1}*\frac{E1}{RGFA} = P*U1*A1*Eeff \quad ...(1)$$

E1 : Energy consumption of rural residential buildings
P : Total national population
P1 : Rural population
U1 : The percentage of rural population in the total population
RGFA : Rural building GFA
A1 : Rural building GFA per capita
E_{eff}: Rural building energy consumption per unit GFA

Building energy efficiency is generally expressed by unit energy consumption of unit GFA. However, RECP does not fully represent the effects on building energy consumption by technical improvement and policy encouragement because it is simultaneously affected by residents' behavior. In other words, different periods of the unit building energy efficiency cannot be directly compared. The influence by residents' behavior should be deducted. This is the same reason with that price effect is deducted when comparing GDP of various years. Therefore, it is necessary to introduce behavioral factors (B) to I = PAT model, called model I = PBAT (Diesendorf 2002). In this paper, the concept of residential energy consumption index is used to measure residents' behavioral effects on building energy consumption, and to compare energy consumption of unit GFA.

Building energy consumption per capita to a certain extent reflects the influence of residents' behavior on the building energy consumption. It is assumed that the influence of residents' behavior on building energy consumption is directly proportional to Building energy consumption per capita (refer to eq. 2).

$$B = kI \quad ...(2)$$

B denotes the influence of residents' behavior on the building energy consumption; *K* is constant, k > 0; *I* denotes building energy consumption index per capita which is used to indicate the trend and extent of energy consumption per capita in different periods. Assumed E^0 is the building energy consumption per capita in year 0, E^T is the building energy consumption per capita in year *t*. If year 0 is assumed as the benchmark time, the building energy consumption index per capita of in year 0 is set as: $I^0 = 100$. The building energy consumption index per capita in year *t* is formulated as:

$$I^T = 100 \times E^T / E^0 \quad ...(3)$$

Building energy efficiency is represented by comparable energy consumption per unit GFA (*T*), which is energy consumption per unit GFA (E_{eff}) after deducting the effect of residents' behavior. *T* is computed by using formula (4).

$$T = E_{eff} / B = E_{eff} / (kI) \quad ...(4)$$

Then, eq. (5)-(7) are used to calculate energy consumption of rural residential buildings (E_1), energy consumption of urban residential buildings (E_2), and energy consumption of urban public buildings (E_3).

$$E_1 = PU_1A_1BT_1 \quad ...(5)$$

$$E_2 = PU_2A_2BT_2 \quad ...(6)$$

$$E_3 = PU_3A_3BT_3 \quad ...(7)$$

Wherein,

U1 : The percentage of rural population in the total population
U2 & U3 : The percentage of urban population in the total population
A1 : Rural residential building GFA per capita
A2 : Urban residential building GFA per capita
A3 : Urban public building GFA per capita
T1 : Comparable energy consumption per unit GFA of rural residential building;
T2 : Comparable energy consumption per unit GFA of urban residential building;
T3 : Comparable energy consumption per unit GFA of urban public building

The effects on building energy consumption by those factors could be summarized as the following model.

$$E = \sum_i E_i = \sum_i PU_i A_i BT_i \ (i=1, 2, 3) \quad ...(8)$$

Factor decomposition is conducted to analyze China building energy consumption by using LMDI method (Ang et al. 1998). During the period [0, T], building energy consumption changes from E^0 to E^T. The integrated influence on building energy consumption is indicated in eq. (9)-(10) by the variation value (ΔE_{tot}) and variation ratio (D_{tot}).

In additive form:

$$\Delta E_{tot} = E^T - E^0 = \Delta E_P + \Delta E_U + \Delta E_A + \Delta E_B + \Delta E_T + \Delta E_{rsd} \quad ...(9)$$

In multiplicative form:

$$D_{tot} = E^T / E^0 = D_P D_U D_A D_B D_T D_{rsd} \quad ...(10)$$

$\Delta E_P(D_P)$, $\Delta E_U(D_U)$, $\Delta E_A(D_A)$, $\Delta E_B(D_B)$, $\Delta E_T(D_T)$ are the devote values (devote ratio) to building energy consumption change driving by population, urbanization, GFA, residents' behavior, and building energy efficiency. ΔE_{rsd} and D_{rsd} are residual values.

The devote value of each driving factor is given in eq. (11)-(20) through applying LMDI method.

Additive form:

$$\Delta E_P = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(P^T / P^0) \quad ...(11)$$

$$\Delta E_U = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(U_i^T / U_i^0) \quad ...(12)$$

$$\Delta E_A = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(A_i^T / A_i^0) \quad ...(13)$$

$$\Delta E_B = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(B^T / B^0) \quad ...(14)$$

$$\Delta E_T = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(T_i^T / T_i^0) \quad ...(15)$$

Multiplicative form:

$$D_P = \exp\left\{ \frac{\ln(E^T / E^0)}{E^T - E^0} \Delta E_P \right\} \quad ...(16)$$

$$D_U = \exp\left\{ \frac{\ln(E^T / E^0)}{E^T - E^0} \Delta E_U \right\} \quad ...(17)$$

$$D_A = \exp\left\{ \frac{\ln(E^T / E^0)}{E^T - E^0} \Delta E_A \right\} \quad ...(18)$$

$$D_B = \exp\left\{ \frac{\ln(E^T / E^0)}{E^T - E^0} \Delta E_B \right\} \quad ...(19)$$

$$D_T = \exp\left\{ \frac{\ln(E^T / E^0)}{E^T - E^0} \Delta E_T \right\} \quad ...(20)$$

There is no residual value when using LMDI method as it is a complete decomposition method. Eq. (21) is derived by adding the both sides of eq. (11)-(15).

$$\Delta E_P + \Delta E_U + \Delta E_A + \Delta E_B + \Delta E_T = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \cdot \left\{ \ln(\frac{P^T}{P^0}) + \ln(\frac{U_i^T}{U_i^0}) + \ln(\frac{A_i^T}{A_i^0}) + \ln(\frac{B^T}{B^0}) + \ln(\frac{T_i^T}{T_i^0}) \right\}$$

$$= \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(\frac{P^T U_i^T A_i^T B^T T_i^T}{P^0 U_i^0 A_i^0 B^0 T_i^0}) = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(\frac{E_i^T}{E_i^0}) = \sum_i (E_i^T - E_i^0) = \Delta E_{tot}$$

$$\Delta E_{tot} = \Delta E_P + \Delta E_U + \Delta E_A + \Delta E_B + \Delta E_T \quad ...(21)$$

Similarly, eq. (22) is given by adding the both sides of eq. (16)(20).

$$D_{tot} = D_P D_U D_A D_B D_T \quad ...(22)$$

To calculate building energy consumption growth rate (R_{tot}), E^0 is divided by both sides of eq. (21).

$$\frac{\Delta E_{tot}}{E^0} = \frac{\Delta E_P}{E^0} + \frac{\Delta E_U}{E^0} + \frac{\Delta E_A}{E^0} + \frac{\Delta E_B}{E^0} + \frac{\Delta E_T}{E^0} \quad ...(23)$$

Devote value of each driving factor to building energy consumption growth rate is denoted by:

R_P, R_U, R_A, R_B and R_T: $R_{tot} = \frac{\Delta E_{tot}}{E^0}$, $R_P = \frac{\Delta E_P}{E^0}$

$R_U = \frac{\Delta E_U}{E^0}$, $R_A = \frac{\Delta E_A}{E^0}$, $R_B = \frac{\Delta E_B}{E^0}$, $R_T = \frac{\Delta E_T}{E^0}$

It should be noted that the accurate number of k is not necessary when calculating ΔE_B and ΔE_T (refer to eq. (24) and (25).

$$\Delta E_B = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(B^T / B^0) = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(\frac{kI^T}{kI^0}) = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln(I^T / I^0) \quad ...(24)$$

Similarly, the formula of calculating is:

$$\triangle E_T = \sum_i \frac{E_i^T - E_i^0}{\ln E_i^T - \ln E_i^0} \ln\left(\frac{E_{eff,i}^T I^0}{E_{eff,i}^0 I^T}\right) \quad ...(25)$$

Data collection and analysis: This paper focuses on the building energy consumption in China from year 2005 to 2009. The data of total population, urbanization, and total GFA are obtained directly from the National Statistical Yearbook. The data of building energy consumption are not available because in China energy Statistical system, only the numbers of energy consumption of primary industry, secondary industry, tertiary industry and residential living are reported. Building energy consumption is not separately released. This is different from the way that the energy consumption reported in developed countries. In China, there are two methods to calculate building energy consumption. One is macro-statistical method, to summarize those building related energy consumption after being separated from China energy statistical database. The other is micro-statistical methods. Firstly, energy consumption value of individual building is collected by measuring the energy consumption of heating system, air-condition system, and lighting system of a certain number of existing buildings. Next, the average energy consumption values of all types of buildings are computed by statistical method. Finally, the total national energy consumption value is concluded by multiplying the total GFA of various types of buildings and corresponding energy consumption value. In this paper, macro-statistical method is adopted. The spin-off of energy consumption of various types of buildings is given in Table 1.

Energy consumption of urban building with central heating is decomposed to residential and public. They are formulated by:

E2 = energy consumption of urban residential buildings (excluding heating) + energy consumption of central heating * ratio of urban residential building area in total building area ...(26)

E3 = energy consumption of urban public buildings (excluding heating) + energy consumption of central heating * ratio of urban public building area in total building area ...(27)

The building energy consumption in 2005-2009 is computed by conducting eq. (26) and (27). It is given in Table 2.

Results: After data collection, the effects of driving factors to building energy consumption change have been analyzed by applying the decomposition model. The results are shown in Figs. 1-3 and Tables 3-4. The following conclusions are given after conducting the above decomposition analysis of driving factors on China energy consumption change.

1. Improvement of living conditions is the most important driving factor of increment of energy consumption. It can be seen from Fig. 3, among those driving factors, that the largest amount of increment of building energy consumption is devoted by residents' behavior, which is 178 million tons of standard coal during 2005-2009, and resulting in 34% of the increment rate. The effect index of en-

Table 1: Building energy consumption calculation.

Building type	Energy consumption sectors	Data sources
Urban public building (excluding heating system)	Transportation, storage, post and telecommunication	Energy consumption in these sectors is mainly produced in buildings. It is defined as building energy consumption. Data derived from Electricity Balance Table of China Statistical Year Book.
	Trading and catering	Data derived from Integral China Energy Balance Table of China Statistical Year Book.
	Others (including consultancy, health, sports, institution, arts, government, and organization)	Data derived from Integral China Energy Balance Table of China Statistical Year Book.
Urban residential building (excluding heating system)	Residents' living	Data derived from China Energy Balance Table of China Sta tistical Year Book.
Urban heating supply system	Coal consumption in boiler room for heating system	Data derived from Coal Balance Table of China Statistical Year Book.
	Coal consumption of cogeneration for heating system	Total coal consumption = coal consumption per GFA * heating supply area* proportion of using cogeneration heating. Coal consumption per GFA: 14kgce/m^2 (BECRC 2008); Heating supply area: derived from Central Heating in Cities by Region table of China Statistical Year Book.
Rural residential building	Residents' living	Data derived from China Energy Balance Table of China Statistical Year Book.

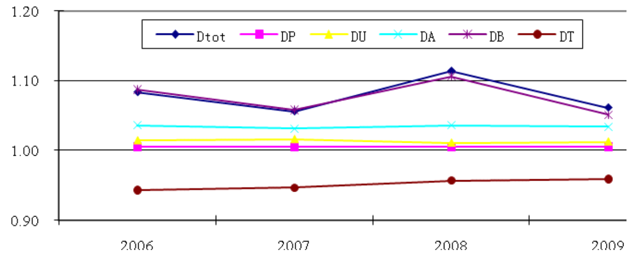

Fig. 1: Decomposition value of driving factors to energy consumption change.

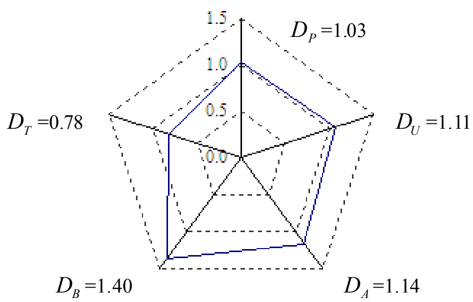

Fig. 2: Effect index of energy consumption change by driving factors in 2009 (year 2005 is the benchmark year).

ergy consumption change by residents' behavior is 1.34, larger than that of the other three factors. Improvement of residents' living condition, as a residents' behavior, is a main reason of causing more energy consumption. For better and more comfortable living conditions, people require more appliances. For example, the demand of air-conditioning for householders in 2009 is increased by 26% comparing with year 2005.

2. Following residents' behavior, increment of total building area is the second important factor of making more energy consumption. The total GFA of new buildings is 38.6 billion m^2 in 2005, and increased to 44.8 billion m^2 in 2009. This increment of GFA produced 8.332 million tons of standard coal, which devotes 34% of the increased rate of energy consumption.
3. Building energy consumption is enlarged by population growth and the advancement of urbanization in China. Although relatively small, the impact is smooth. The effect index remains about 1.01 during 2005-2009 (Fig. 1). The impact of urbanization on building energy consumption is 2-3 times of the impact by change in population. This implies that the structure of population has greater influence than amount of population. In 2009, the changes in population and urbanization factors lead to building energy consumption increment, 12.73 million tons of standard coal and 33.92 million tons of standard coal, composing 2% and 6% of the increase rate, respectively.
4. Enhancement of energy efficiency in buildings is a major factor to decrease building energy consumption. From year 2005 to year 2009, energy saving of 121 million tons of standard coal, beyond the target of the "Eleventh Five-Year" period set by the Ministry of Housing and Urban Construction (Cai et al. 2009), has been achieved by improving building energy efficiency. It decreases building energy consumption by 23%. This achievement is attributed to series of energy saving schemes launched by China government. Such as the Ministry of Finance has invested Yuan 12 billion for improvement of energy efficiency for 180 million m^2 of existing buildings during 2005-2009. Another example is that the supervision of implementation of energy efficiency standards for new construction has been strengthened by the Ministry of Housing and Urban Construction. The new energy saving standard was applied by 90% of new buildings in stage of construction in 2009 with comparing to 21% in 2005.

RECOMMENDATION

In recent years, China is facing the challenge of rapid growth trend of building energy consumption due to growing population growth, accelerated urbanization, increase of building scale and the improvement of living conditions. It can be predicted that it will show a rigid building energy consumption growth in the next 10-20 years. Therefore, effective measures should be taken to slow down the increment speed of building energy consumption. In order to promote energy saving, following recommendations are suggested.

1. Building energy efficiency should be improved through three ways. One is that should release more schemes to encourage research and development of advanced techniques, applications and industrialization. The second is to further strengthen the implementation of building energy saving standard to improve energy efficiency of new buildings. In addition, proper economic incentive policies should be launched to guide the development of green buildings and low energy consumption buildings. Thirdly, continuous investment should be allocated for reconstruction of existing high energy-intensive buildings.
2. Energy-saving activities should be encouraged by improving the energy price system and strengthening people's awareness of energy conservation. To prevent energy waste and excessive energy consumption behavior, it is suggested that residential heating bill should be charged based on the accurate heating consumption, as well as a maximum limitation of energy consumption for public buildings should be set. Furthermore, government should enhance the introduction of environmental friendly consumption awareness so that people may initiatively have behavior in an energy-saving way.

Table 2: Building energy consumption (2005-2009).

		Year				
		2005	2006	2007	2008	2009
Population(Million)		1308	1314	1321	1328	1335
urbanization(%)		42.99	43.90	44.94	45.68	46.59
Building GFA (Million m^2)	Total	38591	40054	41560	43076	44840
	Rural residential	22140	22602	23011	23372	23953
	Urban residential	10769	11289	12078	12893	13724
	Urban public	5682	6163	6471	6811	7163
Energy consumption (Million tons of standard coal)	Total	530	574	607	676	717
	Rural residential	92	97	100	123	132
	Urban residential	242	263	282	310	325
	Urban public	195	214	225	242	260
Energy consumption index per capita		100	109	115	127	134

Table 3: Decomposition of driving factors to energy consumption change.

Year			2005-2006	2006-2007	2007-2008	2008-2009	2005-2009
Additive form(Million tons of standard coal)	energy consumption change	ΔE_{tot}	44.31	32.13	69.28	41.45	187.17
	Population	ΔE_P	2.91	3.05	3.25	3.51	12.73
	urbanization	ΔE_U	8.05	9.66	7.16	9.05	33.92
	GFA	ΔE_A	19.55	18.15	22.58	23.04	83.32
	Behavior	ΔE_B	45.93	33.41	64.38	34.72	178.45
	Energy efficiency	ΔE_T	-32.13	-32.15	-28.10	-28.87	-121.25
Multiplicative form	Variation ratio	D_{tot}	1.08	1.06	1.11	1.06	1.35
	Population	D_P	1.01	1.01	1.01	1.01	1.02
	urbanization	D_U	1.01	1.02	1.01	1.01	1.06
	GFA	D_A	1.04	1.03	1.04	1.03	1.14
	Behavior	D_B	1.09	1.06	1.11	1.05	1.34
	Energy efficiency	D_T	0.94	0.95	0.96	0.96	0.82

Table 4: Decomposition of variation amplitude (2005-2009).

Factors	R_{tot}	R_P	R_U	R_A	R_B	R_T
2005-2009	35%	2%	6%	16%	34%	-23%

3. Renewable energy should be applied in buildings. Application of renewable energy is the fundamental way to reduce China's building energy consumption. With the State's financial support, the application has a good start during "Eleventh Five-Year" period. For further and larger scale application, concentration of contiguous areas with required conditions could make a trial of using of renewable energy in large-scale. In some provinces with sufficient sunshine, solar energy could be a compulsory energy source. Finally, sufficient support from government is essential for boosting the application of renewable energy and related industrial development.

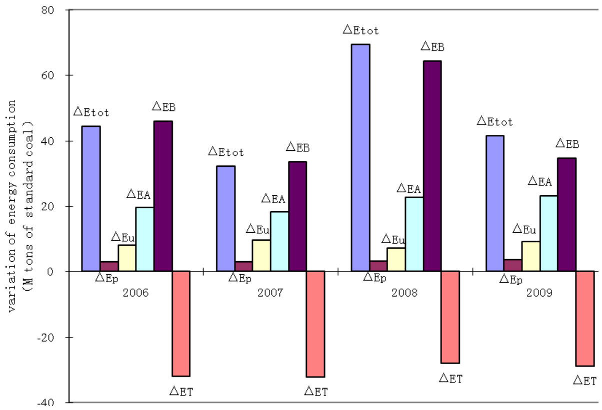

Fig. 3: Decomposition of variation of energy consumption by driving factors.

CONCLUSION

This paper proposes a decomposition analysis model for identifying and calculating the influence of driving factors on building energy consumption in China. The analysis suggests that improved living conditions are the most important factor in China's increased energy consumption, followed by the increased total building area, population growth and urbanisation in China. Improved building energy efficiency is a factor in decreasing building energy consumption. Some general strategies for energy conservation are proposed. These strategies are mostly related to improving energy efficiency through governmental policy, public awareness and action, and technological advances. Improve building energy efficiency and promotion of renewable energy will play an important role in protecting the environment.

ACKNOWLEDGMENTS

The authors would like to thank Yong Wu at the Ministry of Housing and Urban-Rural Development of China for his valuable comments.

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