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Analysis Report of Low Energy Buildings in China

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1 General Description of Low Energy Buildings in China

1.1 The building construction scale is increasing and energy consumption is persisting to rise.

In the recent years, with the repaid development of urbanization, house area per capita is increasing stepwisely. As the result, building construction scale accordingly scales up. At end of 2002, total building construction area of urban and rural in China is 38.8 billion m^2, and 13.18 billion m^2 comes from urban. Only in 2003, the total complete building construction area for urban and rural reaches 2.03 billion m^2, and 1.27 billion m^2 comes from urban.

In the first 20 years of 21st century, Chinese urbanization speed is speeding up; as a result, building construction industry will expand rapidly. It is foreseen that 1.6 to 2 billion m2 new buildings will be constructed every year. Even though with 1.6 billion m2 new buildings, countrywide building construction area will achieve 67.6 billion m2 and 26.1 billion m2 comes from urban by the end of 2020. Based on the forecast by World Bank, half amount of worldwide new buildings will come from China until 2015.

Enormous building scale brings considerable building energy consumption. Table 1-1 lists total energy consumption and building energy consumption. It shows that improvement of energy efficiency associated with regulation of industry configuration, the total domestic energy consumption begin to reduce. The total domestic energy consumption reduced from 1389.5 million ton coal equivalent in 1996 to 1303 million ton coal equivalent in 2000, with 6% reduction rate.

However, domestic energy consumption from buildings presented increased trend. The energy consumption by buildings increased from 334.7 million ton coal equivalent in 1996 to 350.4 million ton coal equivalent, with 4% increased rate. This is because that Chinese government laid particular stress on industry energy saving aspect, and another reason is the increased living standard. Both the two reasons leads the energy consumption caused by building was increasing.

Table 1-1 Total number of domestic energy consumption and number by buildings from

1996 to 2001 [Unit: Million ton coal equivalent (Mtce)]

Year	Total number of domestic energy consumption [Mtce]	Energy consumption by buildings [Mtce]	Ratio between number by buildings to total （%）
1996	1389.5	334.7	24.1
1997	1381.7	341.4	24.7
1998	1322.1	345.7	26.2
1999	1301.2	349	26.8
2000	1303.0	350.4	27.4
2001	1349.1	358	27.5

Source：Data of Ministry of Construction

Although the proportion of by buildings in total energy consumption is increasing, it is still lower than in developed countries. At present, the ratio of energy consumption by buildings to total is about one third, for instance, the number is 33% in Japan, 35% in U.S., 5.5% and 7.5% higher than China respectively. It shows that modernization level in China is still low. With the economic development, the requirements for building comfort in working, entertainment, etc. is increasing. As the result, heating and cooling scope and period become larger and longer. Besides air conditioner, other variety of electrical appliances is also increasing. All the factors enhance the energy consumption in building, approaching the level (33%) in developed countries.

1.2 Energy consumption in building is high and energy saving potential is enormous.

China is the third energy production country behind U.S. and Russia in the world. However, large population leads much less energy for per capita. The coal possessive rate is 50% of the world average level per capita, 12% for crude oil and 6% for natural gas. With the economic development, Chinese energy demand is rapidly increasing, the total number has ranked No.2 behind U.S., and under the condition that energy consumption is only 50% of the world average level per capita. If the number for per capita reaches the world average level, the total energy consumption will be double amount compared with before. If the average number is equal to the number in U.S., the total amount in China will be equal to the consumption by all the countries in the world. Therefore the energy shortage problem has become severe. Chinese industry most depends on traditional energy resources, like coal, crude oil and natural gas, but these non-renewable energy resources are approaching exhausted in the near future.

To support the economic sustainable development and increasing population, energy saving measurement should be firmly stressed. Based on the worldwide experience in recent 30 years, building energy saving technology has the biggest potential and highest efficiency to release the intensity of energy use and solve the conflict between social economic development and energy resource shortage.

In the recent years, developed countries began to focus on the exploitation of renewable energy, such as solar energy, ground source, wind energy, etc. Combined with recyclable material, low energy building is realized and zero energy consumption building is not a dream. Compared with normal buildings, the low energy building has 40% saving rate, even 90% for some cases.

Compare with developed countries, Chinese building construction scale is large but 95% has high energy consumption. Even for new complete buildings in recent years, 90% of the building has high energy consumption, but with uncomfortable living level. Data shows that compare with developed countries in similar climate conditions, the heating consumption per m2 is three times of developed countries, but thermal comfort is much worse.

The reason for high energy consumption in buildings is low energy use efficiency in China. The current energy use efficiency is 33%, 10% lower than developed countries. The energy consumption per production value is double than world average value. The energy consumption for main product from eight industries (petrochemical, electric power, steel, colored metal, constructional material, chemical, light industry and cotton spin) is 40% higher than international advanced level. Operational efficiency of coal fire boiler is 15 to 20% lower than international advanced level. The petrol consumption per hundred km by vehicle is 25% higher than Europe and 20% higher than Japan. The energy consumption for building heating and cooling is both higher than developed countries. All the evidence shows that energy saving potential in China is enormous.

1.3 Building energy efficiency technology develops fast and demonstration building projects complete in succession.

The world development trend of building energy efficiency technology is that each country strengthens the research of the technology, and develops new technology. The relevant technologies include high efficient insulation for complex walls, roof and ground; infrared thermal reflection technology; high efficient insulated glazing; solar energy technology; thermal energy recovery technology; test for new buildings and computer aid technology, etc. Meanwhile, demonstration and spread of pilot project is also important. Last, the relevant standard and affiliated policy are continuously revised to meet the new requirement.

From 1980, the building energy efficiency task was initiated, technical standard was compiled. The pilot project was startup from beginning of 90's. In middle of 90's, policy concerning building energy efficiency was setup and implemented, and "Building energy efficiency - No. 9th plan & layout target for 2010" was established, which clearly defined the policy in China. In the end of 90's, Chinese government began to implement 50% energy saving plan target. At present, Chinese government is actively promoting "Chinese Residence Sunshine Plan" to speed up the utilization of solar energy in buildings. The implementation of "Civil building energy saving management regulation" improved the effective execution of building design standard and expedited exploitation & application of national building energy efficiency technology.

Parallel with promoting building energy efficiency policy by Chinese government, its technology obtained fast development, and numbers of applicable research production was completed, such as insulation technology for walls and roofs, airtight and heat insulation technology for glazing, energy saving heating technology, solar thermal utilization technology, etc. Moreover, many domestic institutes cooperated with foreign countries, such as Sweden, UK, and Canada in building energy efficiency technology, as the result, many advanced technology was introduced into China, promoting the development of the technology in China. The low energy residential building increased from 0.4 million m2 in beginning of 80's to 40 million m2 by end of 90's, 6.75 million ton coal equivalent was saved and 16.55 million ton CO_2 was diminished.

To popularize energy efficiency technology, some demonstration building projects were constructed in succession in big cities. At beginning of 2005, the first low energy building project in China was completed in Tsinghua University. The project collects the most advanced technology in the world, and electricity consumption per year is only 30% of the average number in similar buildings in Beijing. The project installs auto-track solar collector for solar thermal use; dish type solar ray catcher in roof associated with light introductory system to supply light for indoor; 30 m2 PV (max 15 kW power generation) panels are laid at south part of the building, power which generated from PV system is used for driving the glass façade and window blinds; phase change material is laid in floor causing the indoor temperature fluctuation less than 6 ℃. The total energy consumption by envelopes of the building is only 10% of the normal building, and zero energy consumption from heating in winter can be almost realized.

In 2006, Shanghai Ecological Demonstration Building was completed. The project is a key important demonstration building from the project "Key technology research and system integration of ecological building" carried out by shanghais science and technology committee. The PV panels are laid on top of roof; north direction room also has sun light; waste water is recycled into the buildings; controllable sun shade devices are installed. The overall energy consumption is only 25% of traditional buildings. The energy supply by renewable energy is 20% of the total energy demand.

Coming along with development and improvement of technologies, these types of demonstration buildings integrated with advanced energy saving technologies and facilities will come forth in near future.

1.4 More and more Chinese energy efficiency standards came into being, but amendment and improvement is necessary

Energy efficiency standard is the technical measurement and policy from root to control the building energy consumption. Most countries attach importance to the standard compilation, more than 90 countries and districts obtain obvious effect, and more than 60 countries and districts have compulsive standard for new buildings. 40 states in U.S. have its own public building energy efficiency standard, more than 6 state with developed economic (like New York and California, etc) have stricter standard than national standard. The experiences from abroad prove that compulsive standard is a very effective way to promote building energy efficiency activity.

The work about building energy efficiency in China is developing rapidly. By end of 80's, the building energy efficiency standard was extended from freezing district, cold district to hot summer & cold winter district and hot summer & warm winter district; from new buildings, rebuild buildings, extend construct buildings, to existing buildings; from simple residential buildings to public buildings.

Table 1-2 lists current executable building energy efficiency standards in China. The relevant standards are "Standard of Climatic Regionalization for Architecture", and "Thermal Design Code for Civil Building", etc. The "Code for Acceptance of Energy Efficient Building Construction" is compiling so far.

Table1-2 Current executable building energy efficiency standards in China

Standard Name	Execution start time
Energy conservation design standard for new heating residential buildings	1st July, 1996
Design standard for energy-efficiency of civil buildings in hot summer and cold winter zone	1st Oct, 2001
Design standard for energy-efficiency of residential buildings in hot summer and warm winter zone	1st Oct, 2003
Design standard for energy efficiency of public buildings	1st July, 2005

More and more cities begin to focus on building energy efficiency task. Beijing municipality compiled the first national design standard for public buildings. The new "Design Standard for Energy Efficiency of Residential Buildings" requires that if the construction drawing does not fulfill the 65% energy saving design standard, the drawing will not be examined, which means the project will be not allowed to construct. This is the first compulsive design standard for 65% energy saving in China. (65% energy saving means the energy consumed by the new building is 65% lower than the building which does not adopt the energy efficiency method.)

Although 50% energy saving standard is applied to three climate zones, the preliminary energy saving system has been formed, the requirement is still low compared with developed countries. Many aspect needs to be completed and improved, such as not matching and not complete, no any standard can be compared with "Construction Law" and "Energy Conservation Law". The lag of some standards is also not satisfying the new situation. The general standard system for land saving, water saving, material saving and environment protection is not setup.

Standard making is only an instrument. The final target is putting into effect of the requirement in standard by supervision. Therefore, the national law and code have clear requirement. For example, "Energy Law" states that project design and construction invested by permanent assets should comply with the energy efficiency code and standard, otherwise, the construction is prohibited. Ministry of Construction promulgated "Management Regulation for Energy Efficiency of Civil Buildings", "Compulsive Standard Supervision Regulation for Project Implementation and Construction" to strengthen implementation of the relevant codes.

From general point of view, China lacks law restriction and powerful execution organization, standard execution force is still weak. From 1996, less than 20% new residential buildings strictly fit energy saving standard. The task to strengthen the standard application and supervision is urgent and arduous.

2 Composing Analysis of Chinese Building Energy Consumption Status

2.1 Energy consumption in residential buildings

2.1.1 Energy saving status of residential building

In 1989, the beginning of reform and open to the outside world, the occupancy area per head in cities and towns is 3.6 m2. After 20 years endeavor, the occupancy area per head has reached 8.7 m2 in 1997. The number of residential building in rural areas is larger than cities and towns, and the development is faster. However, compared with developed countries (30m2), Chinese residential area per head is still on low level, far below the requirement from habitants. Chinese government has put the residential construction to be the new increasing point of national economy. It can be forecasted that large number of residential buildings will be come forth in the near future. On the other hand, residential building requires comfortable indoor thermal environment, thus, large amount of energy is consumed. Energy occupancy per head in China is short, therefore, energy saving technique has become a fundamental policy as stated in national “Energy Law”.

Heating energy consumption needs to be reduced for the heating district in winter. In July 1996, “Energy conservation design standard for new heating residential buildings, JGJ26-95” started to be implemented. The benchmark of this standard is based on the heating energy consumption in typical residential buildings in beginning of 80’s, which requires that the new residential buildings should save 50% (30% from insulation and 20% from boiler & pipeline) heating energy consumption compared with old buildings. Until so far, some cities and provinces already established the local detail rules for implementing JGJ26-95 standard, including Beijing, Tianjin, Liao Ning Province, Ji Lin Province, Inter Mongolia Municipality, Shan Xi Province, Gan Su Province and Ning Xia Municipality, etc. After 10 years endeavor, there are 80 million m2 new residential buildings which satisfy 30% and 50% energy saving standard. But the status of energy saving is still not optimistic. The 50% energy saving standard is far from the target. The insulation level is low for building envelopes. The reconstruction for old building needs large number of fund and payback period is long, resulting in a great deal of buildings waiting to be reconstructed.

By using air conditioner in summer and heating system in winter is the trend in middle and down Changjiang River district. But it lacks residential energy efficiency design standard, the insulation in old buildings is very poor, resulting in large amount of energy waste. No compulsive measurement with insulation for new residential buildings is also a fact.

In a conclusion, building energy efficiency measure is an inevitable trend. Some result is achieved, especially in Northern part of China. However, many problems are waiting to be solved. The energy saving task for building in middle and down Changjiang River district is blank. Problems with air conditioning system in hot summer and warm winter district are obvious. All the factors bring hard task and big potential as well.

2.1.2 Investigation and analysis of residential buildings in heating district

In order to know the composing and quantity of the energy consumption in residential buildings, we carried out a questionnaire investigation about residential energy consumption in heating districts, mainly in Beijing (Annex 1 with more detail). Totally 64 questionnaires were distributed and 60 were effective. The objects include Beijing, Xi'an, Shi Jia Zhuang, Shen Yang and Harbin (majority in Beijing). Most buildings are high-rise residences (70%), average usable area is 80.6 m^2, and average 2.6 persons per household.

At present, the energy consumption in domestic residential buildings of heating district mainly consists of heating, electricity and gas. Most cities adopt central heating system, whose energy consumption can be calculated by local index of heat loss of building and useable area. The consumption by electricity and gas can be calculated via household-based heat metering. In order easy to analyze the data, final statistical result of the investigation adopts kWh to be the measure unit.

After statistic and computation, the results are shown below:

(1) Energy consumption from heating

In the 60 residential dwellings, 56 buildings own central heating system and another 4 dwellings owns independent heating system. For the 56 dwellings, 52 dwellings are from Beijing, and the rest are from Xi'an, Shi Jia Zhuang, Shen Yang and Harbin. Most dwellings were built between 1997 and 2004, which applied 50%

energy saving standard in Beijing. The index of heat loss in Beijing is 20.6 W/m2, and other four cities are 20.2 W/m2, 20.3 W/m2, 21.2 W/m2 and 21.9 W/m2 for Xi'an, Shi Jia Zhuang, Shen Yang and Harbin respectively.

The calculation was done based on the index of heat loss and building areas for 56 dwellings. The average energy consumption by heating is 6404.8 kWh/dwelling/year.

(2) Energy consumption from electricity

The Fig 2-1 shows that annual electricity consumed is from 500 kWh to 5000 kWh, and most dwellings' consumption is between 1000 kWh and 3000 kWh (48 dwellings).

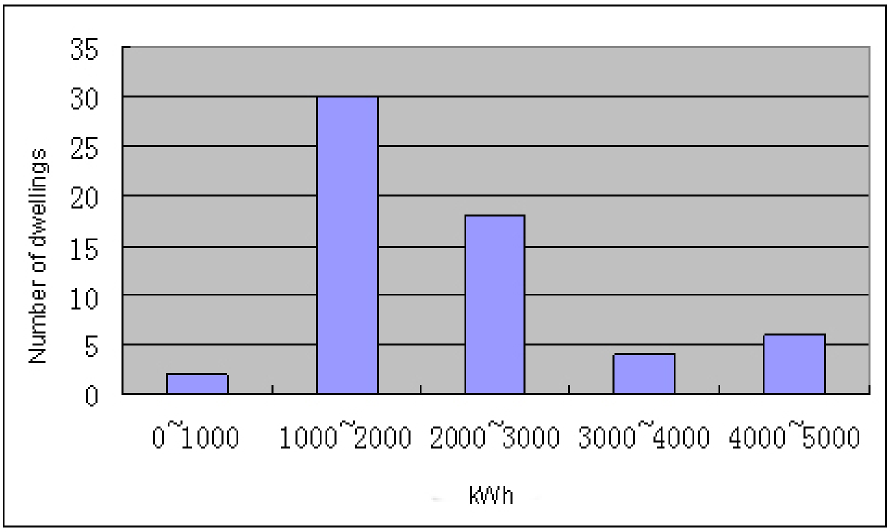

Fig 2-1 Annual data of electricity consumption in residential dwellings

The average electricity consumption in residential dwellings is 2400.8 kWh/dwelling/year, among it, 277 kWh/dwelling/year is for lighting system, 572.2 kWh/dwelling/year is for air conditioner and the rest is 1551.6 kWh/dwelling/year. (Fig 2-2)

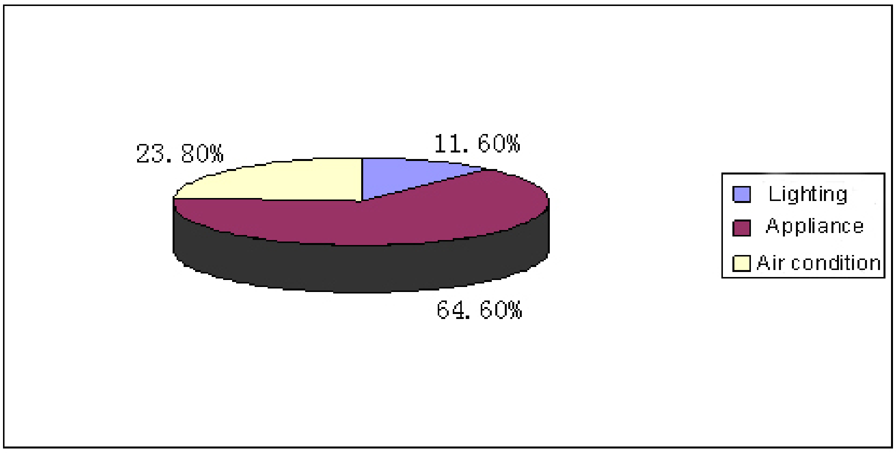

Fig 2-2 Composing of annual electricity consumption in residential buildings

(3) Energy consumption from gas

54 dwellings use fired gas out of 60 dwellings to be the non-heating purpose. The fired gas includes natural gas (49 dwellings), coal gas (3 dwellings), and liquefied petroleum gas (2 dwellings). The current heating value for natural gas, coal gas and liquefied petroleum gas are 8500 Kcal/m^3, 3500 Kcal/m^3, and 11000 Kcal/kg, respectively. The amount of coal gas and liquefied petroleum gas in each dwelling can be converted by heating value into natural gas, the average used quantity of natural gas is 205.7 m^3.

The heating value of natural gas is 8500 Kcal/m^3, which can be converted to 9.9 kW/m^3. After calculation, the average natural gas consumed is 2036 kWh/dwelling/year.

(4) Total energy consumption

Based on the above statistical data, a residential dwelling with central heating system consumes about 10841.6 kWh per year, which is equal to 107.5 kWh/m^2/year according to 100.8 m^2 average building area. The proportion by heating, electricity and natural gas are 59.1%, 22.1%, and 18.8% (Fig 2-3).

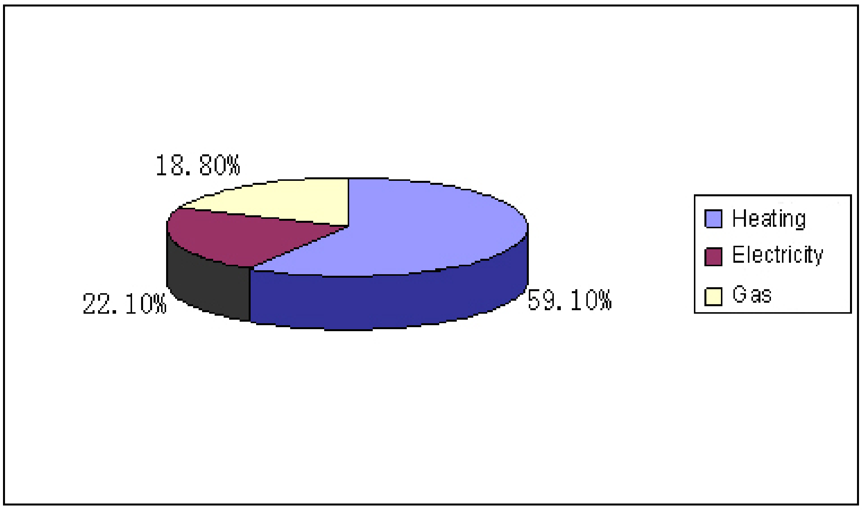

Fig 2-3 Composing of residential energy consumption

It can be seen from above analysis data that Chinese cities has much higher energy consumption in residential buildings compared with cities in similar latitude in Europe.

The third edition of "Heat Insulation Statute" of Germany in 1995 prescribes that the residential building should at least have 100 mm heat insulation layer, the energy consumption should not exceed 100 kWh/m^2, and clearly gives the definition of "Low energy residential buildings". Germany divides the low energy residential buildings into four types, which are energy saving dwelling (Energiesparhaus), low energy dwelling (Niedrigenergiehaus), passive dwelling (Passivhaus), and zero-heating dwelling (Nullheizenergiehaus). The energy saving dwelling should have heat insulation layer thicker than 150 mm, the energy consumption should less than 65 kW/m^2/year. The relevant data for low energy dwelling are 200~250 mm, and 30 kW/m^2/year; for passive dwelling are 300 mm, and 15 kW/m^2/year. The zero heating dwelling almost does not consume traditional energy[1].

According to result from questionnaire, the energy consumption in dwellings of northern heating districts is 107.5 kWh/m^2/year, compared with Germany, which has similar latitude and climate, the level is even below than ten years ago of Germany, mainly because:

(1) The passive design in dwellings is scarce, overall efficiency of

[1] Development and Status of Low Energy Dwellings in Germany, Chen Kunzhou, "Design Community", Feb, 2001.

heating system is low, which causes the energy consumption from heating is dominating in northern heating districts of China, nearly 60%.

In the new buildings in cities and towns of every year, less than 6% dwellings are designed by the building energy efficiency standards. Even though based on building energy efficiency standards, energy consumption of the dwellings is 50%~100% higher than the countries in Western Europe and Northern America, which have similar climate. The comfort level is also low[1]. For example, based on the new standard (65% energy saving) in 2004, much energy consumption from heating of dwellings are reduced. However, compared with Sweden, Denmark and Finland, the number is still 50% higher (Table 2-1). At present, only Beijing and Tianjin comply with the 65% energy efficiency standard.

Table 2-1 Comparison of index of heat loss between Chinese residential buildings and developed countries with similar climate

	Average index of heat loss in heating season （W/m2）
Beijing's dwellings built without energy efficiency standard in 1980	31.68
Beijing's dwellings built with 30% energy efficiency standard in 1986	25.3
Beijing's dwellings built with 50% energy efficiency standard in 1997	20.6
Beijing's dwellings built with 65% energy efficiency standard in 2004	14.65
Dwellings from Sweden, Denmark and Finland	11

The high energy consumption for heating in China has a main reason which is lack of passive measurements. Table 2-2 shows the comparison of heat transfer coefficient of building envelope in design standard between Beijing and overseas cities. The heat transfer coefficient in Beijing is based on "Energy conservation

[1] "Energy Efficiency in Residential Buildings", P5，China Architecture & Building Press, 2006

design standard for new heating residential buildings", which was implemented from 1st July, 1996. The 50% energy saving standard is valid for the most of the dwellings in the investigation. The results shows that the insulation level in Beijing is very low compared with cities in developed countries, which means the energy consumption in heating is much more in Beijing than cities in developed countries.

Table 2-2 Comparison of heat transfer coefficient of envelope between domestic and overseas[1]

Country	Outer wall [W/(m²·K)]	Glazing [W/(m²·K)]	Roof [W/(m²·K)]
Beijing（JGJ26—95）	1.16~0.82	4.0/4.7	0.80~0.60
Southern Sweden	0.17	2.5	0.12
Berlin, Germany	0.3~0.2	1.5	0.20
District in U.S., similar climate with Beijing	0.45~0.32	2.04	0.19
Canada	0.36	2.86	0.40~0.23
Hokkaido, Japan	0.42	2.33	0.23
District in Russia, similar climate with Beijing	0.77~0.44	2.75	0.57~0.33

After the new local standard, "Design Standard for Energy Efficiency of Residential Buildings (DBJ 01-602-2004)", was released in Beijing,2004, the heat transfer coefficient of each part in building envelope was reduced (Table 2-3) [2]. The insulation level of outer wall has approached the level with similar climate cities in Germany, UK, U.S., Russia and Japan. But the glazing performance still needs to be largely improved.

Table 2-3 Maximum value of heat transfer coefficient in each part of building envelope [W/(m²k)]

Residential	Roof	Outer wall	Window/	Under	Floor	Upper floor

[1] Beijing local standard: Design standard for energy efficiency of residential buildings (DBJ 01-602-2004), P33, Beijing municipal commission of urban planning & Beijing municipal construction committee, issued in 2004-06-08, implemented in 2004-07-01

[2] Beijing local standard: Design standard for energy efficiency of residential buildings (DBJ 01-602-2004), P6, Beijing municipal commission of urban planning & Beijing municipal construction committee, issued in 2004-06-08, implemented in 2004-07-01

type		Exterior insulation	Main section of interior insulation	Upper part of balcony door	part of balcony door	contact with air	board of non-heating space
5 floors building and below	0.6	0.6	0.3	2.8	1.70	0.5	0.55
4 floors building and below	0.45	0.45	No restriction				

Most dwellings (75%) in the questionnaire investigation have exterior insulation, 82% dwellings have double glass. But to reach the new energy efficiency standard, these measures are far not enough. Table 2-4 lists average heat transfer coefficient of low energy building envelope and corresponding insulation layer in Germany. It can be seen that to obtain good energy efficient effect, rather thick insulation layer is needed. At present, 40~50 mm Polystyrene board is mostly adopted in Beijing district, and 80~100 mm Polystyrene board in Harbin, which is the coldest city in Northern China. But there is still big gap between these cites in China and Germany.

Table 2-4 Average heat transfer coefficient of low energy building envelope in Germany

Exterior stone wall	U<0.25W/m2K（120-180mm insulation layer）
Exterior wood frame wall	U<0.20W/m2K（200-250mm insulation layer）
Roof	U<0.15W/m2K（250-300mm insulation layer）
Partition wall between heating and non-heating zones	U<0.30W/m2K（80-120mm insulation layer）
Glazing	U<1.3W/m2K（double glass filled with gas）

By improving architecture design, strengthening insulation system and effectively making use of solar energy, the heating demand can be reduced by 1/2 or even 1/3. 60% residential buildings in Northern China adopt central heating system, 30% waste energy is caused by improper regulation and window open. By replacing heating mode, improving thermal grid regulation and thermal efficiency, the energy consumption by heating in Chinese residential buildings can be reduced by 30% of current level.

(2) Energy efficiency lamps and electrical instruments are not popularized, and user's consciousness for electricity saving is still weak, which produce high consumption from electricity.

The electricity consumption in home is mainly for lighting system and home electrical instruments. With the development of living standard and increasing of dwelling area, people owns more home electrical instruments than before, which is shown in table 2-5. So far, the common electricity instruments in domestic home are TV, refrigerator, washing machine, DVD machine, music play machine, drink machine, water heater for shower, smoke suction machine, computer, cleaner, microwave oven, induction cooker, electric cooker, air conditioner, etc.

Table 2-5 Diversification of possession rate of Chinese residential electrical instruments (/hundred dwellings) [1]

Type / Year	1990	1995	1999	2000	2002	2003
Washing machine	78.4	89.0	91.4	90.5	92.9	94.4
Refrigerator	42.3	66.2	77.7	80.1	87.4	88.7
Colorful TV	59.0	89.8	111.6	116.6	126.4	130.5
Video machine		18.2	21.7	20.1	18.4	17.9
Music center		10.5	19.7	22.2	25.2	26.9
Camera	19.2	30.6	38.1	38.4	44.1	45.4
Air conditioner	0.3	8.1	24.5	30.8	51.1	61.8
Water heater for shower		30.1	45.5	49.1	62.4	66.6
Smoke suction machine		34.5	48.6	54.1	60.7	63.6
DVD			24.7	37.5	52.6	58.7
Computer			5.9	9.7	20.6	27.8
Video camera			1.1	1.3	1.9	2.5
microwave oven			12.2	17.6	30.9	37.0

[1] "Energy Efficiency in Residential Buildings", P2，China Architecture & Building Press

Body exercise machine			3.8	3.5	3.7	4.1

For the lighting aspect, the high effective light source is the preference. In the common types of light source, high pressure natrium light has the highest effective, the next are metal halid light & fluorescence light, and incandescent light is the lowest. The common used lights in residential buildings are incandescent light and fluorescence light. Incandescent light is commonly called bulb, which uses electrified tungsten filament. Fluorescence light is also called low pressure mercury fluorescence light, which has irradiance via fluorescence powder blazed by ultraviolet radiation. Compared with incandescent light, Fluorescence light has higher efficiency (5 times), longer life (larger than 2000 hours), softer ray, and lower heat radiation. The illumination intensity of a fluorescence light with 11 watt is equal to incandescent light with 60 watt. Thus all kinds of fluorescence light should be popularized.

The questionnaire shows that 6 dwellings use incandescent light, 24 dwellings use fluorescence light and 30 dwellings use both at same time. Pursuing ornamental effect can bring energy waste. In some ornamental lighting, more then ten incandescent light bulbs are used, if all the light is changed into fluorescence light, much energy will be saved. With the developing of the energy saving concept, fluorescence light will have more market.

For the home electrical instruments, the energy saving instrument is the preference. Among all the instruments, air conditioner, refrigerator and electrical water heater have the biggest energy consumption, and the potential for energy saving is big as well. According to "The maximum allowable values of the energy consumption and Energy efficiency grades for house—hold refrigerators", which was issued in 1st Nov, 2003, the refrigerators are divided into five grades: A, B, C, D, and E. D and E belong to the compulsory eliminative products. After the energy effective index was issued for refrigerators, the air conditioner will be indexed afterwards. The index for air conditioner will refer to the standard system in Europe, which have five grades, the 1st is highest level and 5th is the weakest.

At present, many residents have no consideration about energy saving when they select home electrical instruments, and also no scientific control during using, which bring high electricity consumption. Due to the low temperature before and after heating period, electrical heater is used to aid heating. If improving passive design of residential dwellings, these part of energy consumption can be largely reduced.

(3) Restricted by cooking mode, energy saving from cooker is limited, bringing high gas consumption in China.

The traditional cooking modes in China include fry, braise, boiled, stir-fry, and pot-roast, etc. Some process need small fire for a long time, the gas consumption is high. The investigation shows that if the family has elder and kids in home, cooking fire is always on, the gas consumption will be high after a period.

Gas saving can be realized from energy saving cooking instruments, which has two types. The first type is pressure type, also called autoclave. It increases thermal pressure inside boiler, and water boiling point is also increased, which results fast cooking speed for food, and less energy is used. The second type is multifunction type, which use different compartment to cook two or three types of dishes at the same time, thus the accumulative time for two or dishes is largely reduced. For example, the multifunctional electric cooker has several layer: the lowest layer is the main cooling area for rise, the upper several layer can be used for heating food or residual food by steam.

Most residents think much energy is saved from electricity, paying little attention to gas. But the investigation shows the gas consumption (2036 KWh) and electricity consumption (2400.8 KWh) is very similar for one dwelling per year. The potential for energy consumption from gas is large.

(4) Insufficient use of renewable energy, traditional energy is still dominating.

The available renewable energy includes solar energy, biomass, wind energy and geothermal energy, etc. The most used renewable energy in residential buildings is solar energy. Solar energy is a new industry in China and develops very fast in recent years. It has become the most mature and potential energy resource. The solar resource in China is abundant, two third of the area in China has strong yearly irradiation which is larger than 5.02 million kilo joule per m^2 and annual sunlight period are longer than 2000 hours. Solar energy is very suitable to these areas.

Solar energy is mainly used for producing heating, hot water, electricity and refrigeration purpose. Due to economical reason, hot water production is the mainly usage from solar energy in residential dwellings. Some residential districts are trying to use solar energy to supply heating in winter. Electricity production by solar has high cost, thus it is difficult to implement broadly. Only some residential districts are trying to use the solar energy to supply electricity for public lighting, some solar lamp instruments can be found in market.

Although solar energy develops fast in China, only one dwelling out of 60 in the investigation installed solar water heater. There is a big space for solar energy development.

According to above analysis, the emphasis of building energy efficiency in Chinese residential buildings should be building envelopes (including improving of tiny climate, natural ventilation and natural lighting, etc), heating and air conditioning system, reasonable utilization of solar energy, efficiency increase of lamp & other electrical instruments, and reconstruction of existing buildings.

In a conclusion, the following measurements should be taken to improve the energy efficiency intensity in residential dwellings of heating district:

- Building form and structure should be compact and exterior surface area should be minimized;
- Thickness of insulation in exterior wall, ground and roof should be increased;
- Airproof capacity should be improved to reduce non-controllable airflow;
- Cold and thermal bridge should be avoided;
- Roll window blind or other curtain should be adopted to minimize heat dissipation during night time;
- Area of south window should be increased to receive more solar energy;
- Thermal recovery from waste gas;
- Energy efficiency electrical instruments should be adopted;
- Fully make use of solar energy and other renewable energy resources.

2.2 Energy consumption in public buildings

The public building includes ordinary public building and large-scale public building.

The energy consumption in ordinary public building is similar as residential building, with bigger electricity consumption in lighting and other electrical instruments, and less energy consumption in cooking and hot water production. By improving architectural design and adopting energy efficiency lamp instrument, the energy consumption from air conditioning system and lighting system can be reduced from 30% to 40%.

Much attention should be paid to large-scale public buildings. These type of buildings only have 5%~7% of total building area in cities and towns, but electricity consumed is from 100 to 300 kWh/m^2/year, 10 times of residential buildings (not include heating). In the large-scale and oversize cities, the electricity consumption from large-scale public buildings is larger than total electricity consumption from residential buildings of the whole city. In the electricity consumption from large-scale buildings, 50%~60% is from air conditioning system, 25%~35% is from lighting system and the rest is from elevator and office equipment. Based on the investigation, the electricity consumption could largely vary for same functional large-scale public buildings in same district. Thus, big energy saving potential exists for large-scale buildings and 50% electricity consumption could be saved after analysis.

Prof. Jiang Yi, from Tsinghua University leaded an investigation for more than 300 large-scale public buildings (construction area is bigger than 20,000 m^2) about energy consumption in China, the objects include municipality, shopping mall, hotel, office building, traffic hinge, gymnasium, and entertainment center, etc. Besides heating, electricity consumption status was investigated. Air conditioning system in more than 70 buildings was monitored and tested. Some results are shown in below charts.

Figure 2-3 and 2-4 show the comparison of index of heat loss of building and electricity consumption in whole year between large-scale public buildings, ordinary public buildings and residential dwellings. It shows that electricity consumption in ordinary public buildings is higher than residential dwellings. The energy consumption from heating in large-scale public buildings is lower than ordinary public buildings but electricity consumption is largely beyond ordinary public buildings.

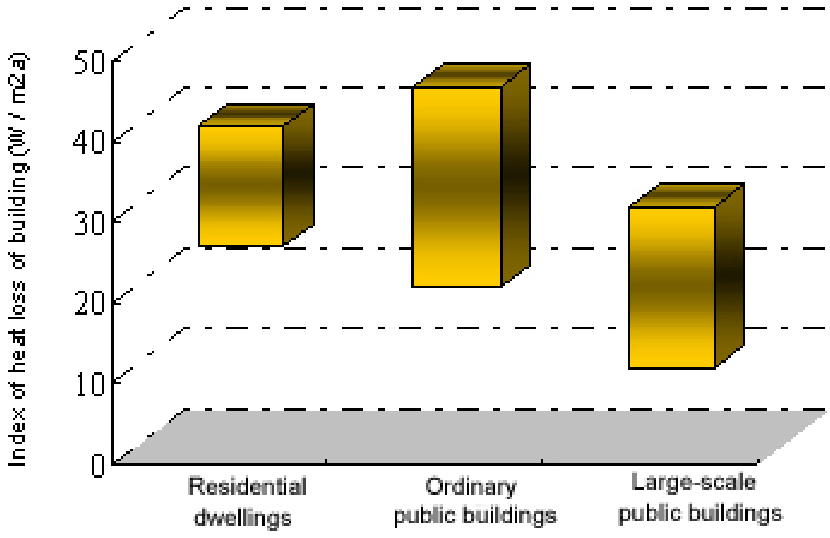

Fig 2-4 Index of heat loss of building in three types of buildings

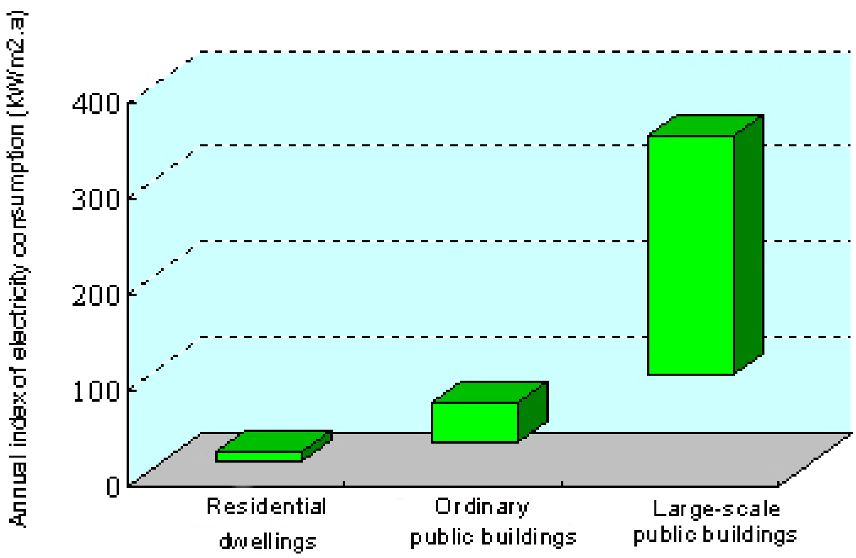

Fig 2-5 Index of electricity consumption of three types of buildings

Fig 2-6 shows the annual index of electricity consumption of large-scale public buildings. Shopping mall has the biggest passenger flow with biggest electricity consumption and hotel is the reverse. Thus the energy consumption in large-scale public buildings is closely relevant to human density.

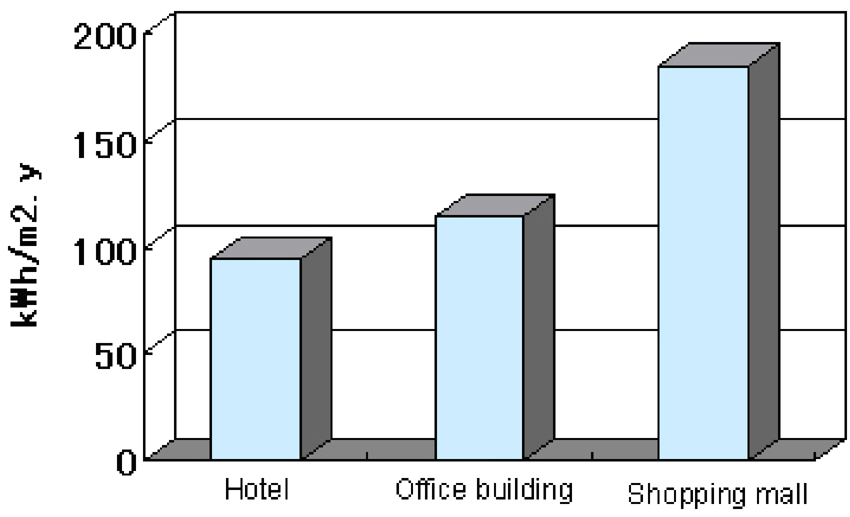

Fig 2-6 Annual index of electricity consumption in three types of public buildings

Fig 2-7 shows the composing of energy consumption from all types of large-scale public buildings. The energy consumption's characteristics of different functional buildings could be found. The energy consumption in shopping mall is simple, most from air conditioning and lighting system. In the office building, energy from computer and office equipment is dominating. No matter what kinds of large-scale public buildings, the electricity consumption from air conditioning and lighting system is always primary.

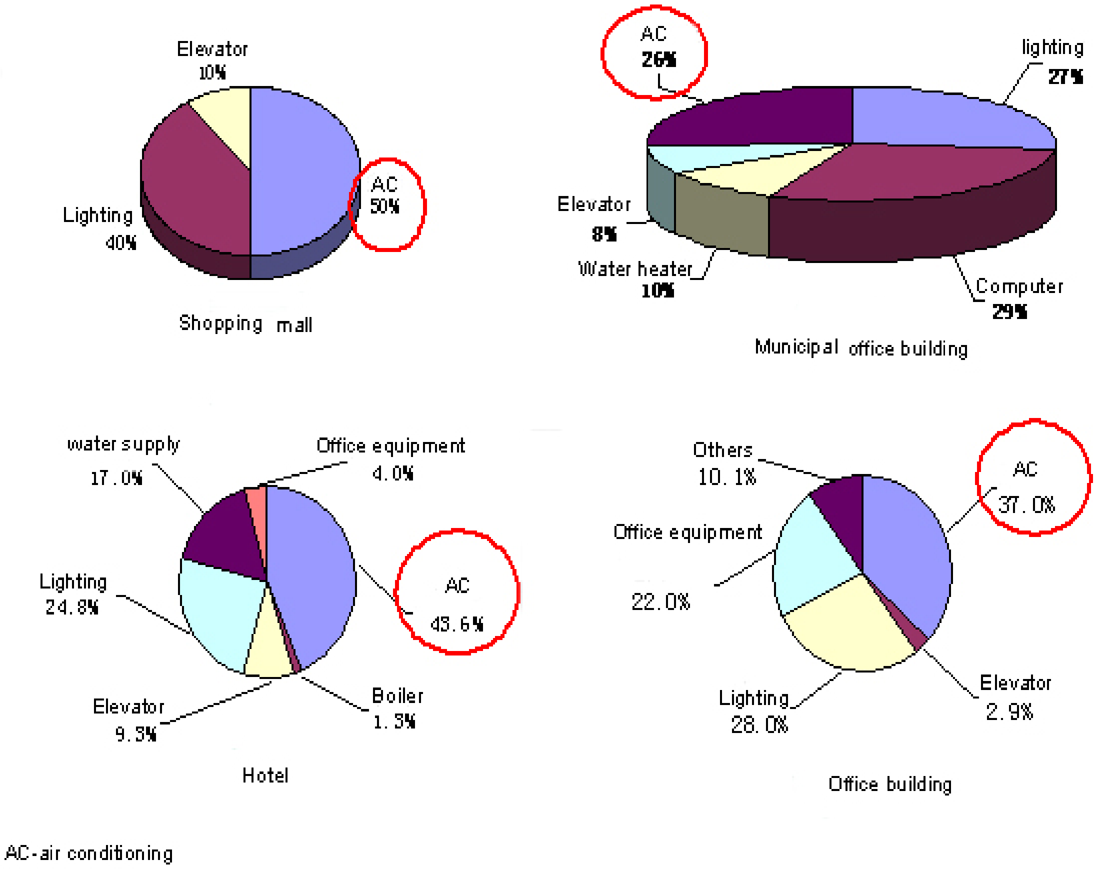

Fig 2-7 Composing of energy consumption

from some types of large-scale public buildings

In a conclusion, the energy efficiency task in China should focus on the passive heating & cooling, heating system, lighting and other electrical instruments, and operation & management of large-scale public buildings. By improving the four aspects, the domestic average energy consumption per m^2 of building could be reduced from 30% to 40%, which means the total energy demand in China could be reduced 10%.

3 Building Energy Efficiency Technology in China

3.1 Energy efficiency technology of building envelopes

The building envelope is seemed like a wadded jacket, whose insulation performance is directly related to building quality and comfortable level. China has a vast territory, and northern part occupies 13 provinces and municipalities, with 6.78 million square km, 72% of the total domestic area. Compared with many developed countries in similar latitude, the northern area in China has colder winter. But the heat transmission from wall, roof, window and door is 2 to 5 times of developed countries with similar climate. Thus the high energy consumption from building envelopes needs to be innovated, and new construction material & technologies need to be largely promoted.

3.1.1 Energy saving from wall and roof

At present, northern area mainly adopts interior or exterior insulation out of building envelopes to improve the heat preservation performance. The exterior insulation has better performance than interior insulation. But the deign of insulation layer is always not fit the standard, bringing large energy waste from heating. In recent years, most influencing projects are Beijing Feng Shang Residential Block, and Modern and myriad city • MOMA in Beijing, who stress on design in building envelopes with 410 mm walls, the insulation layer is deep into ground with 1500 mm. The two buildings adopt low-E double glazing with film plating and airproof measures, adjustable sun shading devices, etc. These measurements effectively control the energy consumption inside buildings, with international advanced level in building envelopes.

However, most building envelopes in areas with hot summer and cold winter, has worse design. Most multi-storey (4-6 floors) buildings in Changjiang River drainage area adopt blending brick structure, its outer wall adopts 240 mm brick wall plus 20 mm plasterer, and the heat resistance is about 0.49 m^2℃/W. The roof is flat with 120 mm hollow floor board plus waterproof layer and 200 mm air ventilation layer, and the heat resistance is about 0.68 m^2℃/W. The glazing adopts single layer glass, with heat resistance 0.16 m^2 ℃ /W. Due to worse insulation and airproof performance, and open window habit of habitants, the indoor temperature is only 2 to 3 ℃ higher than outdoor in winter. Computer simulation shows that indoor temperature in ordinary residence of Changjiang River drainage area is only 5 to 6 ℃, very cold. In summer, the solar radiation intensity is large and people feel muggy inside house. Especially the residence in top floor will have strong roast feeling. The “Design standard for energy-efficiency of civil buildings in hot summer and cold winter zone” began to be implemented at 1st Oct.2001, which requires energy efficiency measures. By referring to measurement in northern areas, thicker insulation layer and some kinds of sun shading measures are adopted to improve thermal comfortable level in winter and summer.

For the building in hot summer and warm winter zones, heat insulation for its envelopes is emphasized, such as complex wall with air interlayer, green wall for plant to speel, and all kinds of heat insulation roof (water storage roof, aerial roof, planting roof), etc.

3.1.2 Energy saving from door and window

Door and window are the weakness of the building envelopes for energy saving, whose performance is decided by heat preservation performance (heat transfer coefficient) and air permeable capability (air-impermeability.). Table 3-1 lists window performance of common windows. It shows that the heat transfer coefficient between ordinary window and wall has large difference. Improving the air-impermeability of window and door is very important to the energy saving of whole building envelopes.

Table 3-1 Physical index of several types of windows

Types	Heat transfer coefficient K（W／m2•K）	air-impermeability A（m^3/m•K）
Single layer glass with plastic frame	4．63	1．20
Double layer glass With painted plates frame	3．75	0．83
Double layer glass With Aluminum Alloys frame	4．20	1．12
Double layer glass with plastic frame	2．37	0．53

Double layer and thermal break high energy efficient glass with aluminum alloys frame	2．23	0．5

At present, double glass low-E glazing is widely adopted due to its good airproof and heat insulation performance, such as Modern and Myriad City • MOMA, Beijing Tiptop International Apartment, and Nanjing Landsea Garden. The heat transfer coefficient can reach 1.2 W/m^2K, cooperated with proper exterior sun shading devices, the good energy saving performance could be achieved.

In a conclusion, the following techniques should be developed and promoted for doors and windows:

- High performance airproof technique for door, window and glass curtain wall;
- Dew temperature control and install technique for high performance double glass and economical double glass glazing product;
- Special material thermal break technique for door, window and glass curtain wall;
- Heat insulation and model technique for door, window and glass curtain wall;
- Integration technique of solar energy and door, window and glass curtain wall;
- Fixedness and filling technique for door, window and glass curtain wall; aerodynamic energy saving technique.

3.1.3 Building sun shading

Building sun shading is a natural, economical and applicable measure to reduce energy consumption. Solar radiation is a precious resource to earth, but excessive radiation in summer brings high indoor temperature, ultraviolet hurt and dazzle, etc. Building sun shading is one of the best ways to solve the problems.

Building sun shading can be realized via building structure, exterior equipment (canopy, board, shutter, and curtain, etc), and evanescence, etc. The exterior equipment is divided into exterior shading device, interior shading device, and shading device inside middle glass. For the energy saving performance, the exterior sun shading is the best and interior sun shading is the worst (table 3-2). Compared with traditional interior sun shading mode, exterior sun shading refuses 80% thermal energy out of doors.

Table 3-2 Solar radiation gain coefficient of diversified glazing system

Palce	Type	Radiation gain coefficient（s）	
		Single layer	Double layer
Interior sun shading	Shutter slice of bottle green & hollow plastic	0.62	0.56
	White & movable soft shutter	0.46	0.46
	White cotton texture curtain	0.41	0.40
	Milk white & cotton linen soft shutter	0.30	0.33
Shading device inside middle glass	White & movable soft shutter		0.28
	Shutter slice of bottle green & hollow plastic		0.17
Exterior sun shading	Canvas curly shutter curtain	0.14	0.11
	White shutter slice with 45 degree obliquity	0.14	0.11
	bottle green & small size shutter slice	0.13	0.10

European countries lead the building sun shading technology, especially for exterior sun shading technology. Even northern European countries like Norway and Sweden, widely use exterior sun shading technology. In conjunction with the technology, a mature market was formed. To solve contradiction between lighting and sun shading aspects, high performance insulation board and thermal reflection sun shading glass are produced. On the other hands, many new type of glazing products have good sun shading performance, such like low-E glazing, multi-functional film plating glazing, membrane reflection material & film paste glazing, and light induce color change glazing, etc.

So far, most buildings in China only have interior sun shading devices, with poor energy saving performance. It's gratifying that some demonstration building has adopted exterior sun shading devices, such as adjustable sun shading curly curtain and shutter, etc. These kinds of low cost but high efficient measures will become popular in near future.

3.2 Natural ventilation technology

Natural ventilation happens when pressure difference exist between two spaces. Good ventilation improves indoor thermal comfortable level and air quality. Meanwhile, air conditioning operational time is reduced and energy saving is achieved. According to driving force, building natural ventilation is divided into three types, i.e. natural ventilation caused by wind pressure differences, thermal pressure differences and mechanical assistant.

3.2.1 Natural ventilation by wind pressure

This type of natural ventilation use the pressure difference between building windward and leeward side, the commonly called "draught" (wind goes through the whole rooms inside building) is the typical example. Wind pressure is related to building shape, angle between building and wind, and surrounding building layout, etc.

To realize ideal natural ventilation by wind pressure, following measurements are adopted to domestic buildings:

- Selection of good exterior wind environment (average velocity is not less than 2~3 m/s);
- Building south façade is faced to dominant wind direction in summer. Combined with short depth of the room, it is easy to realize "draught" happen;
- Combination layout of different buildings, arrangement of bounding wall, trees, which can induct wind distribution and improve surrounding wind environment.

3.2.2 Natural ventilation by thermal pressure

Natural ventilation caused by thermal pressure is also called Stack Effect. The principle is that hot air rises and discharges from top of building and meantime, the fresh and cold air from outdoor is absorbed from bottom of building. The alternation of air inside building is formed. The more height difference between wind inlet in bottom and wind outlet in top, the more strong effect will be caused by thermal pressure, and natural ventilation effect is more obvious.

Many European countries adopt ventilation silo to realize thermal pressurized ventilation. The ventilation silo only can be seen in some public buildings in China, such as low energy demonstration building in Tsinghua University. Compared with wind pressurized ventilation, the air flow speed is low caused by stack effect. To get satisfied wind speed, wind pressure need to be supplemented.

3.2.3 Mechanical assistant ventilation

For the large-scale public buildings, such like stadium, exhibition hall and shopping mall, etc, due to the long wind pipe and high resistance of the pipe, wind and thermal pressurized ventilation are not enough to realize air exchange requirement. For the big cities with serious air and noise pollution, directly natural ventilation will bring dirty air and noise into buildings, causing bad impact to human's health. The above mentioned conditions need to be aided by mechanical ventilation, which is via following measures:

- Maximum efficiency of ventilation via reasonable ventilation design;
- Adoption of high efficient ventilation equipment;
- Control of good ventilation time, frequency and intensity.

3.3 Indoor energy efficiency lighting technology

3.3.1 Energy saving from natural lighting

Indoor lighting includes natural lighting and artificial lighting.

Natural lighting includes direct solar radiation and sky diffusion. Natural ventilation brings many benefits. First, it fits the basic requirement of lighting. Second, it offer diverse visions and enough communication with outside views, eyes and mood is relaxed. Last, electricity is saved by natural lighting, which is one of the important aids of building energy efficiency measures.

Similar as architecture, natural ventilation has long history. People build house for shelter, and design window for lighting, and ventilation. From last century, convenient and high efficient electric light was invented and did a great contribution to human's life, as a result, people began to neglect natural ventilation. Some buildings focused on sculpt and shape but sacrificed natural ventilation. However, with the running out of traditional energy resource, natural ventilation is regaining recognition.

At present, following measures are used by Chinese buildings to realize natural lighting:

1. Enough window opening area

Many buildings have big size south direction window, natural lighting is ensured but energy consumed from window is large in winter time. How to balance the problem between natural ventilation and less energy consumption is need to be solved in near future.

2. Avoiding Shelter

Shelter has big influence to indoor natural lighting. Some buildings have big size window opening area but dim lighting inside building due to the shelter reasons. Shelter comes from other buildings, parts of building itself, trees and virescence, and sun shading devices, etc. Sun shading devices refuse high solar radiation but natural lighting is also refused. To solve the contradiction, scientific design of shading components is important. For example, appropriate angle of reflection board will convert direct sun radiation into soft diffusion light, indoor illumination condition and lighting uniformity is improved.

3. Making use of optical devices

Some buildings make use of optical devices to lighting inside building, such as reflector, light conduct fibre system, light conduit system, etc. These devices conduct light far from the place where has no lighting condition. For example, low energy demonstration building in Tsinghua University use light conduit system to conduct light into basement and first floor with good effect.

3.3.2 Energy saving from artificial lighting

When the natural lighting is not fulfilling the visual requirement, artificial lighting is needed to be the supplement.

It is commonly recognized that the principle for establishing energy efficiency policy and statute is saving electricity as much as possible when enough lighting quantity and quality is ensured. Electricity saving is by adopting high energy efficient lighting products, optimization of lighting system design, etc, but lighting quality should not be sacrificed.

Following measures are adopted in domestic buildings:

1. Reasonable lighting system design

System design is the first step for lighting saving. Reasonable standard lighting grade is important, the grade has three levels: high, middle and low. Second, proper lighting mode is also important. Place with high lighting grade requirement should adopt mixing or divisional lighting mode.

2. High effective light source

Irradiance efficiency is equal to the ratio between luminous flux from light source and electric power consumed by the light source. It reflects the capability of light source in converting electrical power into visible light. The high effective light source is preferable in order to fully making use of electrical power. In the common types of light source, high pressure natrium light has the highest effective, the next are metal halid light & fluorescence light, and incandescent light is the lowest. The common used lights in residential buildings are incandescent light and fluorescence light. Compared with incandescent light, Fluorescence light has higher efficiency (5 times), longer life (larger than 2000 hours), softer ray, and lower heat radiation. The illumination intensity of a fluorescence light with 11 watt is equal to incandescent light with 60 watt. Thus all kinds of fluorescence light should be popularized.

3. High effective lamps

Lamp efficiency is equal to the ratio between luminous flux from lamp and electric power consumed by lamp. It reflects the capability of lamp in converting electrical power into visible light. The high effective lamp is preferable in order to fully making use of electrical power.

Based on the light distribution types, the common used lamps in residential buildings can be divided into direct type, semi-direct type, diffusion type, semi-indirect type and indirect type. Direct type has the highest efficiency and indirect type is the worst.

In the common condition, indoor lamp's efficiency should higher than 70%, and outdoor lamp's efficiency should higher than 55%. Based on different conditions, reasonable control of lamps is very important. Besides, thermal energy produced from lamps can be used by air conditioner, which is so called integrative system by lamps and air conditioners.

4. Usage of electronic ballast

The commonly used fluorescence light is by using gas discharge electricity, which discharges electricity by arc and this type of mode must be cooperated with ballast in series. The ballast has two types, electron and inductance. Compared with inductance type ballast, electron type ballast has advantages, such as lower startup voltage, lower noise, lower temperature, lighter weight, and no stroboscopic action, etc; it can save 10% energy with lower power consumption (50%~70%), and lower overall input power (18%~23%)

5. Controllable lighting system

Controllable lighting system can fit various requirement to realize electricity saving. Based on the variation of natural light, illuminating range for electrical lighting system could be arranged. Divisional control and increasing of switch points are very important. Centralized and controllable management or automatic controllable lighting devices are suitable for public areas in residential district.

3.4 Indoor thermal environment control technology

Thermal comfort is the people's satisfactory consciousness state to thermal environment. Favorable indoor thermal comfort is one of the important conditions to guarantee the good residential environment. The comfortable living temperature is from 18℃ to 22℃ in winter, and from 25℃ to 28 ℃ in summer. When the outdoor temperature is too low in winter and outdoor temperature is too high in summer, heating equipment is needed in winter and air conditioning system is needed in summer to maintain the indoor thermal comfort level. The energy consumption for heating and cooling is over half of the total building energy consumption in China, which brings big potential for energy saving.

3.4.1 Indoor heating

In China, the heating scale is huge, index of heat loss is high, energy waste and environment pollution is severe. High energy consumption is the key factor which restricts heating development in China and brings severe air pollution in cities. Energy saving from heating is the effective way to reduce the total energy consumption and air pollution.

According to investigation to heating consumption from boiler in 2000, index of heat loss in Beijing is 20.4 kg/m^2 coal equivalent, which is three times of the value in developed countries (6.8~10 kg/m^2 coal equivalent). If effective energy saving measures for heating are adopted, the existing energy consumption can extend the heating scale to 3 times as before.

The following measures are adopted to realize building energy saving from heating in China:

- Reasonably reduce indoor heating temperature (For example, reduce from 18～20 ℃ to 16～18 ℃);
- Improve working efficiency of heating system and thermal utilization efficiency(For example, use high efficiency boiler; install thermostatic control valve in heater, etc);
- Building envelope and improve insulation thickness of pipeline;
- Household-based heat metering system

The above measures can reduce the energy consumption per m^2 from 50% to 65%. Some energy efficiency buildings adopt floor or ceiling radiation heating system, whose radiant density is big and efficiency is high, largely improving the indoor thermal comfort.

3.4.2 Indoor Cooling

With the development of national economy and living standard, air conditioning began to enter normal homes.

In 1st of March, 2005, “The minimum allowable values of the energy efficiency and energy efficiency grads for room air conditioners” (GB 12021.3-2004) was implemented. Hence, all the air conditioning products in the market are pasted with energy efficiency label (Fig 3-1). The label has five grades, based on different EER value (energy efficiency ratio), with different colors. If the EER value is bigger than 3.4, the grade is 1. Similarly, 3.2 to 3.4 is grade 2, 3.0 to 3.2 is grade 3, 2.8 to 3.0 is grade 4 and 2.6 to 2.8 is grade 5. Higher EER value presents that more electricity will be saved.

Fig 3-1 Energy efficiency label

In the bottom of the energy label, EER value, input power and cooling capacity are shown. The EER value is the ratio of cooling capacity to input power.

To improve integrated energy usable efficiency, combined heating cooling and power generation system is used by some energy efficiency buildings. The combined system uses the waste heat from power generation to produce heating (or hot water) and cooling. The low energy demonstration building in Tsinghua University adopts a set of gas driving combined heating, cooling and power generation system. The system has four power generation units, including gas engine, Stirling engine, fuel cell, and micro-turbo. Four cooling machines include electrical chiller, double effect combined waste heat absorption Chiller, solution chiller, and liquid dehumidification system. Three heating sources include heating grid, combined heat and power, and flue gas condensation heat, which are energy saving and safe compared with traditional energy sources.

3.5 Utilization of renewable energy

Renewable energy consists of solar energy, biomass, wind energy, and geothermal energy, etc. Solar energy is the most mature renewable energy used in buildings in China.

3.5.1 Utilization of solar energy

Solar heating, hot water supply, and electricity generation is the main range to use solar energy. Due to the economical level in China, hot water supply by solar water heating system is the main usage of solar energy in Chinese residential buildings. Solar water heating system consists of centralized system and distributed system. The common resident use distributed system, i.e. one home has one solar water heater. This mode could save water, easy to manage, no conflict, and suitable for families with less residents. However, for the whole residential building, compared with centralized system, distributed system has its disadvantages, such as higher total cost, lower energy efficiency, inconvenient maintenance, bad visual effect, etc. With the performance development of solar water heating system, centralized (unit) solar water heating system and solar combined other energy sources to supply hot water have become the new research emphasis.

Photovoltaic cells (PV) have too high equipment cost to popularize in building construction. Only some districts use PV system to offer public lighting electricity. This situation can only be improved by reducing the electricity generation cost of PV system.

3.5.2 Utilization of biomass

The use of biomass is centralized in rural area of China. The advantage of biomass usage in rural area is high integrated usage efficiency and complete recycle.

Therefore, good economical benefit can be achieved. For example, waste from rural area can be converted into biogas, so the sanitation condition is improved and traditional energy is supplemented. A study case in Zhe Jiang Province: To solve the river pollution by waste leavening from a solvent production factory (called Jin Hua Yong Kang), a solution was given: the waste leavening from factory can be processed to be the feedstuff for pig, manure from big is fermented to produce biogas, and biogas is for living energy, liquid produced from fermentation process can be used to plant and breed. Green vegetable can be inversely used for feeding pig. A biologic cycle is well formed and good social, economical effect is achieved.

3.5.3 Utilization of geothermal energy resource

Geothermal energy is a clean energy resource. Its characteristics are high thermal flow density, easy to collect and transport, stable quality (flow and temperature), easy to use, etc. It is not only a mine resource but valuable tour resource and water resource. It has become an exploitation hotspot.

China has abundant geothermal energy resources. More than 2500 places with geothermal energy have been exploited. The annual geothermal energy quantity is 1.04×1017 kJ, which is equal to 3.56 billion ton coal equivalent. Exploitation and usage of geothermal energy resource have important meaning to the regulation of national energy structure and improvement of recycling economy.

In buildings, geothermal energy can be used for heating, cooling, hot water supply and entertainment & health care, which has been widely applied in Iceland, Turkey, Japan, U.S., Italy and Philippine, etc.

China is now promoting ground source heat pump technology, which uses thermal resources from aquifer (including underground water, soil and surface water, etc) to supply heating or cooling sources for high efficient air conditioning system. Aquifer energy comes from solar energy, restoring in soil, sandstone and groundwater, which has characteristics in wide distribution, huge storage, quick renewable speed, constant quality and easy to collect, etc. The indoor required temperature in China is 18℃ in winter and 27℃ in summer. Slightly upgrading from geothermal energy, the energy will fit the indoor temperature requirement and it can completely replace traditional energy resources. Because geothermal energy has higher efficiency in heating and cooling, ground source heat pump can save 60% energy compared with ordinary air conditioning system. Nanjing Feng Shang Residential Block project uses the ground source heat pump system in multi-storey buildings.

3.6 Intelligent control technology

Building intelligent control technology uses computer and network communication technology to realize the management for whole building equipments. It covers digital communication technology, control technology, computer network technology, TV technology, optical fiber technology, sensor technology and database technology, etc. Reasonable configuration and design of building intelligent control system largely improves the operational efficiency of building equipments, and reduces system operational energy consumption.

The most popular building intelligent control systems in China mainly consist of seven parts:

1. Communication automation system (CAS)

CAS is the basic system for building phonetic, data, and image transmission. It is connected with exterior communication network, such as public telephone network, integrated services digital network, internet, data communication network, and satellite communication network.

2. Office automation system (OAS)

OAS is a combined system of computer network and database, which use multimedia technology to offer a working mode integrated in character, phonetic, and image, realizing share of information resource and high efficient business mode. OAS has played very important role in the daily working in many industries, such like government, finance, science and technology, enterprise, and press, etc.

3. Building automation system (BAS)

BAS is the system that central computer system network connects distributed and supervised regions, and realizes centralized management and distributed & controllable integrated supervised system under hierarchical control structure. The target of BAS is completely and efficiently supervising and managing all the equipments inside building, ensuring all the equipments in high efficient and optimal operational state. BAS is commonly responsible for air conditioning system, water supply system, thermal & cold resources, power supply, lighting system, elevator and equipment in parking place, etc.

4. Security automation system (SAS)

SAS has regular closed circuit television supervision system, entrance guard system, security and alarm system, electronic patrol system, etc. It works in 24 hours, supervising important region inside building and public region outside building. When danger and disaster happen, SAS will show alarm and adopt strategy immediately to protect people's and estate's safety.

5. Fire alarm system (FAS)

FAS is a computer system which has the functions of fire alarm and fire control linkage system.

6. Generic cabling system (GCS)

GSC is an establishment of constructing communication routeway in intelligent control system. It lays fiber communication cable, copper core communication cable and coaxial cable in cable groove inside building to get to each terminal. It supports various speed communication.

7. Intelligent building management system (IBMS)

By using computer network and integrated system software, IBMS integrates the separated equipment, function and communication in many subsystems into a mutual relative, complete and harmonious network. The network is an integrated operational platform which covers communication collection, analysis, treatment, exchange, and share, etc. IBMS is the top supervision and management system in the building. It makes communication and function in each subsystem high efficiency, reasonable distribution and share.

Low energy demonstration building in Tsinghua University and Shanghai ecological demonstration building both adopt building intelligent control technology, all the equipments inside building are completely supervised, controlled and managed. Operational target for each system is well achieved and building energy efficiency is largely promoted by the technology.

4 Developing prospect of Chinese low energy buildings

4.1 New built construction will be dominant recently, reconstruct for energy saving of old building will be assistant.

In existing buildings of China, more than 95% buildings have high energy consumption. Annually 2 billion m^2 new buildings are built. According to the forecast from World Bank, till 2015, half amount of the civil buildings is newly built after 2000. Therefore, energy efficiency measures for new buildings are highly urgent. Compared with new buildings, reconstruction for energy efficiency for existing buildings is more difficult. Thus, if the fund is restricted, energy efficiency measures for new building are more preferential, which include establishment and implementation of energy efficiency standards, new technology exploitation and application of building equipment, etc.

In fact, progress of energy efficiency renovation for existing buildings is very slow due to the policy reason but not technical reason. Responsibility is not clear for each organization in the policy, so fund is difficult to put into effect. All the organizations should put into effect to solve the problem.

Firstly, government should be the example to promote building energy efficiency. Most developed countries have series financial and tax policy support to building energy efficiency task. But China is lack of such financial and tax policy support. Many efforts need to be done. For example, regular budget from government should be setup to support technical development, demonstration, promotion, investigation and supervision; Certain proportional fund from long term national debt should be the contribution to building energy efficiency task; Fund for wall renovation should be changed to building energy efficiency fund; Taxation reduction of some building energy efficiency products.

Secondly, all social elements should undertake the responsibility together, especially for real estate company, institute which owns building property right and building client. For the government, building energy efficiency measures can save traditional energy and protect environment; for the client, thermal comfort is improved and building operational cost is saved; for the property management company, maintenance cost is saved and for real estate company, building quality is improved and lifespan is extended. Therefore, invest from all aspects is worthy and benefit for all aspects is active. In a word, all the social elements should promote the building energy efficiency task together, and fund shortage will be solved from various orientations.

4.2 The building energy efficiency measures should have pertinency, i.e., different types of buildings should have different stress point.

China has a vast territory with large diversity climate from east to west and north to south. Different climate zones have different energy composition with different emphases for energy saving task. According to the climate regionalization in “Thermal Design Code for Civil Building, GB50176-93”, China is divided into five climate regions, i.e. chilliness region, cold region, hot summer & cold winter region, hot summer & warm winter region and mild region.

Heating equipment is necessary in chilliness and cold regions, which has centralized or distributed system. The energy consumption from heating will be half of the total energy consumption. Therefore, the building energy efficiency measures mainly depend on heat transmission reduction from building envelopes and efficiency improvement of heating supply grid. The former aspect requires properly controlled of building shape coefficient; improvement of insulation for exterior wall, door, glazing, roof and ground and improvement of air tightness for door and glazing. The latter aspect requires reasonable load control of boiler; adoption of water pipe grid equilibrium technology and improvement of heat preservation for heating pipeline, etc.

Downstream region of Changjiang River in hot summer and cold winter climate has high population density and higher developed economy. This region has fervent summer, indoor temperature is higher than 35℃; and cold winter, indoor temperature is lower than 10℃. Due to the lack of traditional energy, although this region has bad thermal environment in summer and winter, heating equipment is not available in winter and natural ventilation is the only way to reduce temperature in summer. Therefore, the energy efficiency measure should stress on passive design of building envelopes.

The region in hot summer and warm winter climate also has high population density and higher developed economy. Although winter in this region is warm, summer is extremely hot. The building energy efficiency measures lay particular stress on heat insulation, heat dissipation, such like aerial roof, sufficient sun shading, natural ventilation, air-interlayer wall, etc.

In the recent year, with the fast development of the national economy, people living standard is largely improving. In the hot summer & cold winter region and hot summer & warm winter region, many residents buy air conditioner and electrical heater to improve the indoor thermal environment, but on the other hand, electricity consumption is also largely increased in these regions. The building passive design can improve the regulation capacity of indoor thermal environment and largely reduce the electricity consumption.

In a conclusion, residential building has lower energy consumption, the building passive technology can largely reduce the energy consumption from heating and cooling system, and effectively improve the indoor thermal comfort. Therefore, the energy efficiency measures should focus on building envelope technology and optimization design in conjunction with development of new technology for building equipment. Compared with residential building, public building has much greater operational energy consumption in heating system, air conditioning system, lighting system and office equipments. The energy saving measures should focus on the new technology and optimized control technology for these systems in conjunction with passive design for building envelopes.

4.3 Energy efficiency technology and measures in low energy buildings is approaching maturity.

The high building energy consumption lies in three aspects. First, improper design and laggard technology bring low efficiency of energy system. Second, outdated equipment has bad performance. Last, operation, maintenance and management are not reasonable, for example, water leakage from pipe; vacant run of elevator; excessive lighting, etc. The first aspect need to be improved by optimization design and adoption of new type energy efficient equipments. For the second aspect, large amount of fund is needed to update outdated equipments. The third aspect can be solved by energy efficiency measures and strengthening of operation, maintenance and management to the building equipments.

At present, The building energy efficiency technology is developing rapidly. The high energy consumption in some buildings are not because of technical bottleneck, but because lack of scientific operation and management, which can largely reduce the energy consumption. The fact proves that constitution and implementation of a low or even zero cost and completed operational management plan for building equipment is the most acceptable way and worthy to promote for client to solve the high building energy consumption problem.

In 2001, Shanghai Jin Mao Mansion adopted low cost and zero cost energy efficient measures in operational management for building equipment system, and gained good effect. For example, the parallel glide door was changed to rotary door to protect cold wind entering from outside building and cool air losing from inside building; all the pumps in cooling system were added frequency conversion devices to adjust cooling water outlet and condensation water inlet temperature based on outdoor temperature and indoor usage condition; changeable exhaust system for kitchen was adopted with installing indoor temperature sensor and light sensor, so the indoor temperature and smoke density can be detected and quantity of exhaust system in off and non-cooking period can be reduced, meanwhile, electricity from fan is reduced, energy efficiency is improved; optimization of indoor air pressure balance system avoid excessive conditioned air flow leakage to outside building. All the measures successfully reduce 20% energy consumption and 30% lower than other buildings in similar climate region.

Besides, some other public buildings like Shanghai Hong Qiao Mansion adopt low cost and zero cost energy efficient measures in operational management for building equipment system, such as optimization of lighting period, region and brightness; use of energy efficient lamps; flexible adjustment of on/off and temperature of central air conditioning system according to climate change; alarm of shutoff of computer and other office equipments when off duty; use of electricity cost difference between day and night, use of energy difference between fresh air and air conditioning system, night natural ventilation and ice storage technology are used to reduce the air conditioning system load in daytime; stop some elevators in non-peak period to increase the usage efficiency of elevator system, etc. All these measure achieved considerable energy saving effect.

4.4 More low energy demonstration buildings will be completed, speeding up the popularization and

development of energy efficiency technology

60% buildings in northern cities & towns of China adopt centralized heating system. Around 30% energy waste in heating system comes from over heat inside building due to improper adjustment in terminal user and window open. In conjunction with low efficiency of small coal fired boilers and poor heat preservation performance of heating grid, integrated efficiency of total heating system in China is 80% lower than developed countries. Besides, the operational efficiency of central air conditioning system in public buildings is low, especially the fan and water pump which are responsible to transport and distribute heating and cooling load consume 60%~70% total electricity of air conditioning system in public buildings. Last, building envelope has poor insulation and heat preservation performance, compared with developed countries with similar climate, energy consumption per m2 in China from wall, roof is 3~5 times of the value in developed countries and 2~3 times for glazing.

It is forecast by experts that improving the heating mode in northern cities can reduce 20%~30% energy consumption in centralized heating system; improving energy efficiency technology for public buildings and operation, maintenance, management for equipments can save 35%~50% energy; adoption of energy efficient material and components for building envelope, and improving insulation, heat preservation and natural ventilation have 30% energy saving potential. Besides, if PV system is used in roof or façade and phased change material in floor (release heat in night and absorb heat in daytime in summer; absorb heat in daytime and release heat in night in winter) is used, zero energy consumption building can be built.

Therefore, from theory point of view, it is mature and feasible to build energy efficiency building or even zero energy consumption building in China. Only market promoting is lacking. Some low energy demonstration buildings are continuously built in Beijing and Shanghai to demonstrate all kinds of energy efficient, ecological, and humanity building mode and advanced product. With the development of scientific technology and human's understand to economical society, these types of demonstration buildings will become more and more. After the energy efficient technology used in these buildings are updated and become more feasible, the cost will be largely reduced and mass production will be realized. It can be forecast that in the near future, all the technologies will enter the true life.

4.5 Construction standard for low energy building will be published, combined with relevant evaluation index system, whole supervision and evaluation mechanism will be formed.

In order to standardize the evaluation system for building energy efficiency performance, many developed countries have their own standard and evaluation index system. For example, the third edition of “Heat Insulation Statute” of Germany in 1995 gave the definition of “Low energy residential buildings” and relevant restriction; U.K. published "Building Research Establishment Environmental Assessment Method，BREEAM”; U.S. published “Leadership in Energy and Environmental Design，LEEDTM”; Australia published “National Australian Building Environmental Rating System Project, NABERS” and Japan published “Comprehensive assessment system for building environmental efficiency, CASBEE”, etc. These standards and evaluation index system effectively promoted the standardization for low energy building’s construction.

Therefore, China is necessary to have its own standard for “Low Energy Building”. The standard should give the rating system based on building energy consumption and thermal performance of envelopes, and higher rating grade has better energy saving performance.

Besides standards, the industry standards of architectural design, structure, water supply, heating ventilation & air conditioning, electric should adjust according to reality. The design code should be continuously revised and new standard and code should replace the old ones if it is necessary.

The promotion for building energy efficiency is a social task. Therefore, standard propaganda and training need to be strengthened; consciousness and technical level of energy saving for management staff and technical staff involved in building construction need to be improved;

The “Standardization management statute of project construction” should be implemented as soon as possible; neaten the order for management system of project construction standard; constitute and complete “Management statue of building energy efficiency”, and “Construction Law” and consolidate energy efficiency requirement and standard implementation for residential buildings &

public buildings.

Last but not least, examination and acceptance for building energy efficiency task are needed to strengthen. The implementation condition of standards and standard constituting condition should be included in the qualification management and examination standard of design and construction department. All the implementation departments should improve the consciousness and recognition degree of carrying out building energy efficiency standards.

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