

## Research on Building Energy Consumption Situation in Shanghai

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**Abstract:** This paper surveys the present situation of building energy consumption in Shanghai and points out the problems of insufficient energy consumption statistics based on the survey data. We analyze the relationships of energy consumption between the building and the whole society, and between the building and the air conditioning system. Eight public buildings in Shanghai have been chosen for analyzing the characteristics of energy consumption of the air conditioning system in real time.

**Key words:** building energy consumption; air conditioning system; public buildings; investigation

### 1. INTRODUCTION

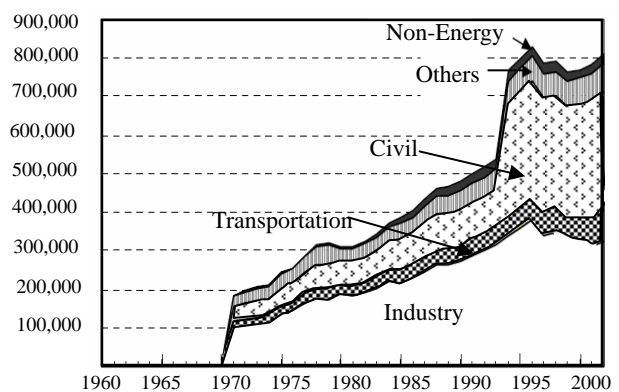
Chinese 11th 5-year-plan has been implemented and started from year 2006. Energy issue is a very important issue during this period of time, because it directly has a huge impact on whether China can sustain the high speed growth rate on economy. Building energy consumption, which accounts for about one fourth of energy consumption of the whole society and is still increasing steady annually, becomes a very hot topic. The laws and regulations regarding building energy-saving will be strengthened and promoted.

However, we don't have an objective and overall evaluation on the building energy consumption currently. No systematical and consistent standard measurement for building energy is available. The basic energy consumption index data is incomplete and can't be shared. All these make it extremely difficult to have a correct evaluation on building energy consumption. It also becomes very tough to establish a reasonable energy-saving standard. In the mean time, it has undermined the development and application of energy-saving technology.

This paper surveys the present situation of building energy consumption. It analyzes the existing problems and points out some research topics through the sample investigation on some buildings in Shanghai area with regard to their air conditioning systems and energy consumption.

### 2. BUILDING ENERGY CONSUMPTION IN SHANGHAI

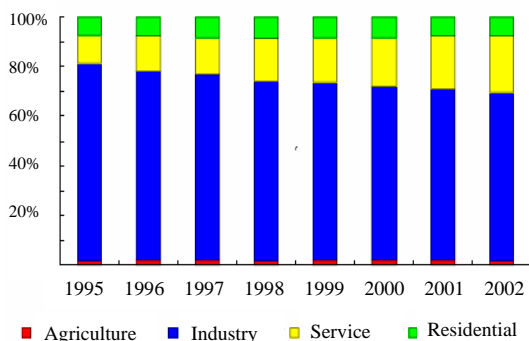
Currently, energy consumption statistics in China are classified into three categories: the primary industry (agriculture, fishery, stockbreeding), the second industry (mining, manufacturing, energy supply, water supply and construction), the third industry (transportation, business trade, service, culture) and the civil consumption. The building energy consumption is not listed as an independent category, but mixed within business trade service and civil consumption. In order to compare with the data of oversea, Fig.1 gives data on the categories of industry, transportation, civil consumption. From the diagram we can see that, civil consumption, which includes the building energy consumption, has been increasing rapidly since the middle of 1990's, along with the construction industry growth.



**Fig.1 Proportion of energy consumption in China[k toe]**

According to the statistics <sup>[1]</sup>, the national average building energy consumption has reached the level of 18.2% of the entire social commodity energy consumption (energy consumption for operation). The percentage is expected to rise further in the coming years, due to the continuous development of China's cities construction.

Because the method used by China to classify energy consumption data is different from that of oversea (Fig2), and there is not clear definition on building energy consumption, it is difficult to correctly evaluate the current situation on building energy consumption.



**Fig.2 Energy consumption mix of each sector in Shanghai**

Currently, methods for calculating building energy consumption and the related researches have drawn a lot of attention. Some researchers have been involved in activities like establishing database, etc.

However, building energy consumption investigation systems have already been established in many countries such as USA and Canada. The American and Canadian governments force all local

**Tab.1 Statistical methods of building energy consumption in different areas**

Areas	Statistical methods	Annotation
Shanghai	questionnaire & scene-testing by nongovernment	detailed and reliable data; few samples; not typical data
USA <sup>[2]</sup>	data from energy departments and questionnaire by government	detailed, typical and reliable data
Canada <sup>[3]</sup>		
Japan <sup>[4]</sup>		
Hongkong <sup>[5]</sup>	data from energy departments and	complex data and sources;

UK <sup>[6]</sup>	questionnaire by government or nongovernment	
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buildings to submit the questionnaire table, and make comparison with data provided by the energy departments to ensure the reliability. Tab.1 gives statistical methods of building energy consumption in different areas.

The building energy consumption is regional dependent; In north region, heating dominates the building energy consumption. In the south region, majority of that is on public building, and air conditioning takes nearly half of the building energy consumption. Air conditioning is powered by the electricity primarily, thus creates the summer electricity supply shortage. The proportions ranged from 30% to 50% of building electricity consumption of cities in China have been shown in Fig.3. Taking Shanghai as an example, the electricity power consumption is increasing annually and electricity shortage keeps happening these years (Fig.4). In year 2003, the peak-to-peak of electricity is 7.4 million kW; in year 2005, the peak load for the electricity power grid is 16.68 million kW, surpassing the capacity of generator and the gap is 3 million kW.

Therefore, reducing the energy consumption on building becomes an effective long term solution for the energy-saving. It is clear that how to uses the technology to reduce the electric power on air conditioning is the key to alleviates the city power shortage problem. To do that, we first need to have an objective correct understanding of building especially air conditioning energy consumption.

### 3. ENERGY CONSUMPTION OF PUBLIC BUILDINGS IN SHANGHAI

The development of residential building construction is very rapidly in Shanghai. But in terms of energy consumption, public buildings have a bigger share of energy consumption. For example, in Shanghai, the area of public building combined accounts for about 14% of total construction area, but it consumes about 55% of total building energy (Tab.3). As is shown in Fig.5, the floor area growth of public buildings is faster than that of residential buildings in recent years. The problem is even more

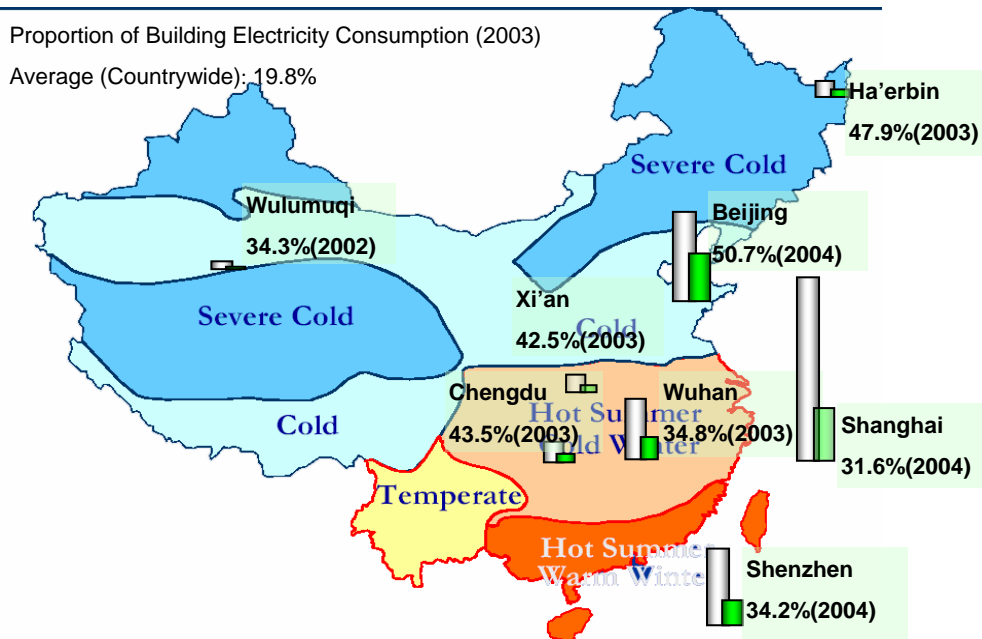
prominent for large public building.

According to the investigation result of 200 using for public buildings are shown in Tab.2. Basically the air condition system takes the electric power as mainly energy source (82%), and heating system takes the energy source as both electrical energy and petroleum which respectively occupies one half.

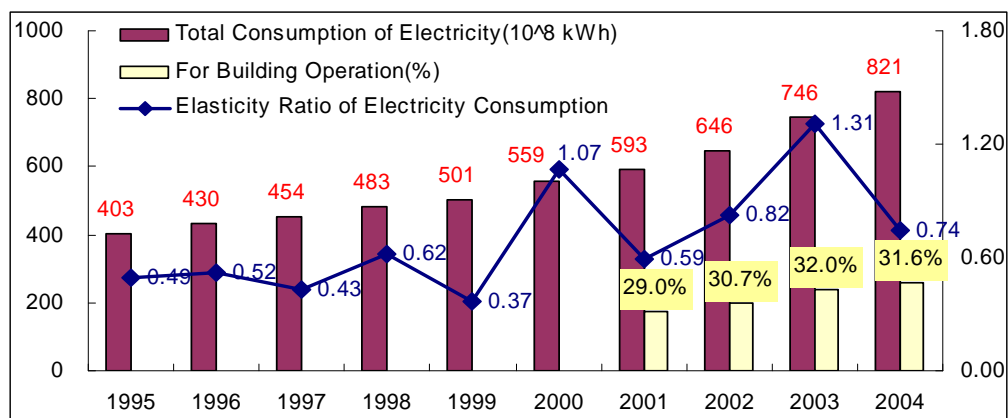
Shanghai High-rise Buildings<sup>[7]</sup>, energy source type

**Tab.2 Energy type for Shanghai high-rise buildings (Samples=200 in Shanghai)<sup>[7]</sup>**

	Electricity	Oil	Gas	Coal
Cooling Sources(%)	82.0	14.0	4.0	0
Heating Sources(%)	43.7	46.0	7.8	2.5



**Fig.3 Proportion of building electricity consumption of cities in China<sup>[8-16]</sup>**



**Fig.4 Trend of electricity consumption in Shanghai<sup>[9]</sup>**

**Tab.3 Public buildings Vs residential buildings<sup>[8-9]</sup>**

Building Category	Energy Consumption (10,000tec)				Electricity Consumption (10 <sup>8</sup> kWh)			
	China		Shanghai		China		Shanghai	
Public	10932.6	36.2%	700.7	55.0%	1534	40.7%	169.2	65.1%
Residential	19268.4	63.8%	573.2	45.0%	2238	59.3%	90.6	34.9%
Sum	30201.0	100%	1273.9	100%	3772	100%	259.9	100%

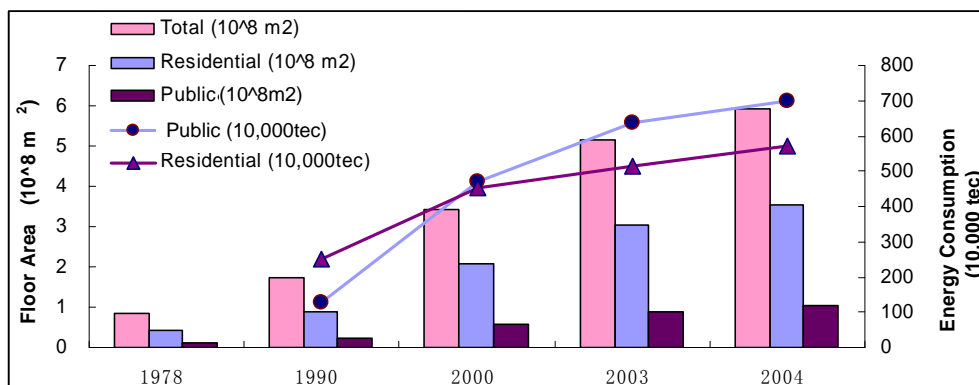


Fig.5 Increase of floor area and energy consumption of buildings in Shanghai [9]

Building energy consumption is respectively measured and counted by different functions in many countries, such as HVAC, heating, hot water and lighting, etc. Lack of respective data of building energy consumption in Shanghai has undermined the analyzing impacts of different part on building energy-saving. Therefore, three typical buildings (office building, store and hotel) have been chosen for scene-measurement and investigation. The energy consumption data of three typical buildings are shown in Fig.6~8.

The energy consumption of public building is huge, and the consumption from air conditioning is the major contributor which accounts about 50% of the total construction energy consumption. There are three ways to solve the energy problem, namely (1) enhancing thermal isolation on building so reduces the thermal load (2) improving air-conditioning system to be more rationality, up the system and equipments efficiency (3) better the operation and management of the equipment and system.

However so far we can see some problems as following.

- 1) The law and regulation related energy-saving has not enough power, the action is not decidedly because of the lack of co-operation administration and education.
- 2) The thermal load calculation is roughly and superfluous, caused equipments selection is big than actual needs, and the efficiency is lower.
- 3) Poor installation of equipments and systems.
- 4) Lack the professional operation management for building equipments and systems.

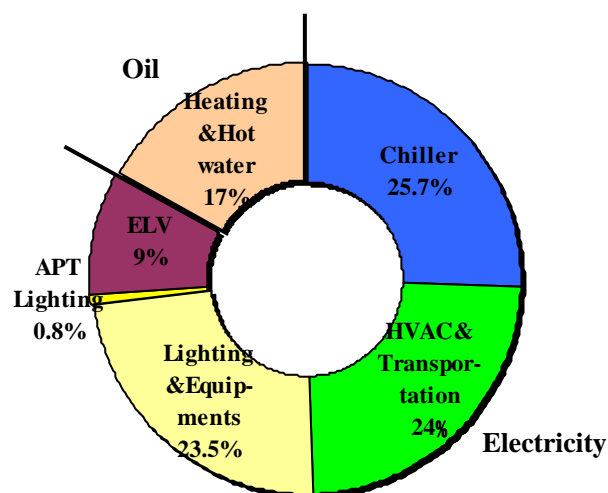


Fig.6 Primary energy consumption proportion of one office building in Shanghai

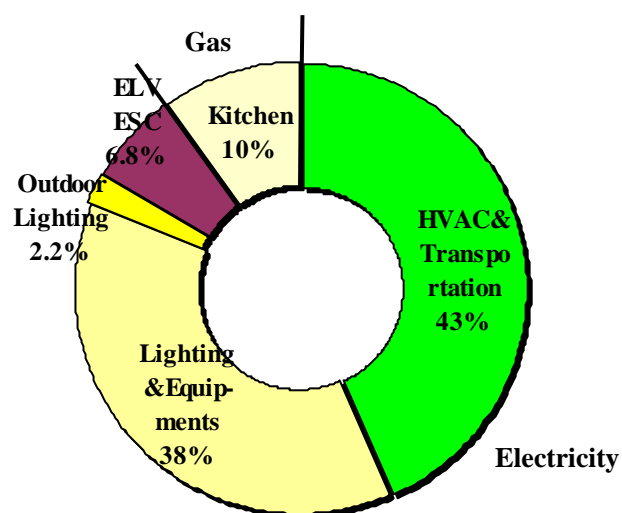
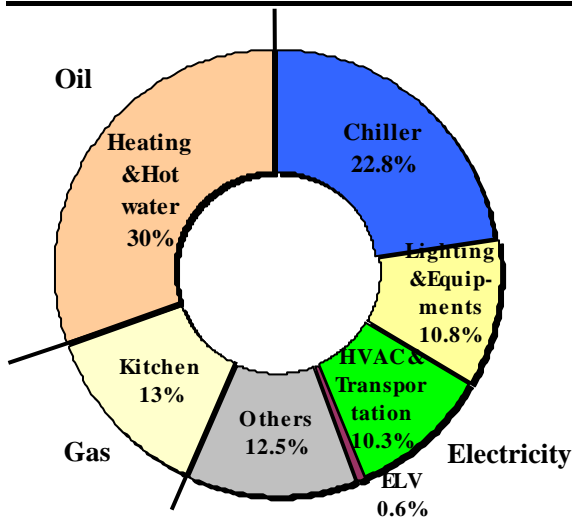


Fig.7 Primary energy consumption proportion of one store in Shanghai

But it is hard to see clearly the real situation about building energy consumption, equipments efficiency and system performance etc. Therefore, we selected 8 public buildings to identify real situation



**Fig.8 Primary energy consumption proportion of one hotel in Shanghai**

and problems regarding energy consumption. It would be some hints for farther study.

The index of commercial building energy consumption in Shanghai is 1.490~3.699 GJ/m<sup>2</sup>·y, which has the average value(2.408 GJ/m<sup>2</sup>·y) 29.0% higher than that in Changsha city ( 0.93 GJ/m<sup>2</sup>·y) [17]

shown in Tab.4. It is due to the difference of building grade.

Taking average energy consumption for A,B,C three buildings (1.678 GJ/m<sup>2</sup>·y) as a index, it is higher than standard in Japan(1.256 GJ/m<sup>2</sup>·y), but is lower than that of average index (1.956 GJ/m<sup>2</sup>·y). It is thought to be a result of overworking in Japanese buildings and consume more energy.

For hotel building (F, G building), the index of energy consumption (3.284 GJ/m<sup>2</sup>·y) is 30.7% higher than standard in Japan (2.512 GJ/m<sup>2</sup>·y) [7] , and also 7.9% higher than that of average index 3.044(GJ/m<sup>2</sup>·y). It is thought to be a result of high end hotel and lower operation level in Shanghai.

**4. CONCLUSIONS**

- ◆ Building energy consumption greatly increased in Shanghai and public buildings have a big share of it.

Building	Primary Energy System	Floor Area (m <sup>2</sup> )	Annual Primary Energy Consumption (GJ/m <sup>2</sup> ·y)						
			Electricity	Natural Gas	Oil	Total	Average	Standard in Japan	Average Data in Japan
<b>Office</b>									
A	C(e)+B(g)	77,690	1.399	0.091	0	1.490			
B	C(e)+B(e)	50,000	1.783	0	0	1.783			
C	C(e)+B(e)	81,000	1.760	0	0	1.760	1.678	1.256	1.956
<b>Compound Functions</b>									
D(Office /Hotel/Store)	C(e)+B(o)+ WSHP	170,000	2.159	0.110	0.6	2.869			
E (Office /Apartment)	C(e)+B(o)	80,697	1.349	0	0.278	1.627	2.248		
<b>Hotel</b>									
F	GHP	10,000	1.506	1.362	0	2.868			
G	C(e)+B(o)	20,000	2.207	0.518	0.974	3.699	3.284	2.512	3.044
<b>Store</b>									
H	C(e)+B(g)	17,440	2.856	0.309	0	3.165	3.165		3.012

C(e):Electrical Chiller; B(e): Electrical Boiler; B(g):Gas Boiler; B(o):Oil Boiler; WSHP: Water Source Heat Pump

**Tab.4 Investigation Results of Real Building Operatio**

- ◆ The energy consumption statistics in Shanghai is insufficient, a database regarding building energy consumption is necessary
- ◆ The laws and regulations regarding building energy-saving will be strengthened and promoted to ensure the energy-saving project.

The investigation only has conducted through partially region in China. We should continue the research co-operate with others and overseas to give more clearly solution for building energy-saving.

## REFERENCES

- [1] Weiding Long. A consider on strategy of building energy-saving in China. *HV&AC*, 2005, (35):1-8.(In Chinese)
- [2] Energy Information Administration, Commercial Buildings Energy Consumption Survey. <http://www.eia.doe.gov/emeu/cbeccs/contents.html>
- [3] Commercial and Institutional Building Energy Use Survey 2000, Detailed Statistical Report
- [4] Japan Statistics Bureau, Japan Statistical Yearbook. <http://www.stat.go.jp/english/index.htm>
- [5] EMSD, Hong Kong Energy End-use Data 2005. [http://www.emsd.gov.hk/emsd/c\\_download/pee/hkee/udb-trad.pdf](http://www.emsd.gov.hk/emsd/c_download/pee/hkee/udb-trad.pdf)
- [6] Department of Trade & Industry in the UK, Energy Consumption in the UK. <http://www.dti.gov.uk>
- [7] Weiding Long. Analysis of energy consumption status and energy efficiency potentials of commercial buildings of Shanghai. *HV&AC*, 1998, (6):13-17.
- [8] National Bureau of Statistic of China, China Statistical Yearbook 2005(In Chinese)
- [9] Bureau of Statistic of Shanghai, Shanghai Statistical Yearbook 2005(In Chinese)
- [10] Bureau of Statistic of Beijing, Beijing Statistical Yearbook 2005 (In Chinese)
- [11] Bureau of Statistic of Ha'erbin, Ha'erbin Statistical Yearbook 2004(In Chinese)
- [12] Bureau of Statistic of Chengdu, Chengdu Statistical Yearbook 2004(In Chinese)
- [13] Bureau of Statistic of Wuhan, Wuhan Statistical Yearbook 2004(In Chinese)
- [14] Bureau of Statistic of Wulumuqi, Wulumuqi Statistical Yearbook 2003(In Chinese)
- [15] Bureau of Statistic of Shenzhen, Shenzhen Statistical Yearbook 2005(In Chinese)
- [16] Bureau of Statistic of Xi'an, Xi'an Statistical Yearbook 2004(In Chinese)
- [17] CZ Yang, Energy consumption status and energy-saving potentials of air conditioning system in public buildings of Changsha. *HV&AC*, 2005(10):39-41(In Chinese)