# Progress in energy efficiency standards of residential buildings in China's severe cold and cold zones

Zhenyu Yu<sup>1,2,\*</sup>, Wei Xu<sup>1</sup>, Xi Chen<sup>1,\*</sup>, Deyu Sun<sup>1</sup>, Jing Zhang<sup>1</sup>, Fei Lu<sup>1,2</sup> and Changping Liu<sup>1</sup>

<sup>1</sup>China Academy of Building Research, Institute of Building Energy and Environment, 100013 Beijing North 3rd ring east road 30, China

<sup>2</sup>Tsinghua University, Building Science and Technology Department, 100084, China

**Abstract.** Since Chinese government released the first residential building energy efficiency standard in 1986, the energy efficiency of residential buildings have been improved significantly. Three editions of residential building energy efficiency standards in severe cold and cold zones have been issued in the past 30 years, meanwhile, a new version is in the course of development and will be released in 2018. The paper reviews energy efficiency standards that have been issued for residential buildings in severe cold and cold zones in China, and development of new energy efficiency standards. The paper also describes the variation of key requirement in standards. Finally, future prospects for further developing energy efficiency standards for residential buildings in China are addressed. The findings show that the energy consumption reduction percentage has raised from 30% of JGJ 26-86 to 65% of the JGJ 26-2010. The insulation performance of roofs and external walls increased respectively by 103% and 83%, and the window performance increased by 130%.

## 1 Background

For purposes of coping with the climate change and energy saving, building energy efficiency has developed rapidly in the past 50 years. The standard is an important tool to promote building energy efficiency. Building energy efficiency standards and regulations are policy measures widely used to control energy consumption in buildings. It can help overcome some of the significant market barriers and ensure that cost-effective energy efficiency opportunities are incorporated into new buildings. This is especially important in developing countries where the number of new buildings is growing rapidly and the energy prices and market often do not encourage the use of efficient technologies. Research by Nadel [1] (1997) showed that trends towards increased use of efficiency standards are likely to continue, along with periodic updates to standards and growth in programs that complement them.

There are almost 1.5 billion m<sup>2</sup> buildings built each year in China over the past 20 years, and nearly 70% are residential buildings. Residential buildings have a big energy saving potential. As one of the world's most rapidly developing economies, energy safety and environmental protection are urgent in China. As China government is likely to maintain rapid economic growth rates, the strategy for providing energy services and ensuring efficient use of energy is very important for China. So the government pay more attention to building energy efficiency with the development of economy.

Development of building energy efficiency standards has been an important issue in China. As energy consumption in buildings accounts for a significant portion of total societal energy requirements and is growing very fast, the potential for energy saving in the building sector is tremendous. The China building energy efficiency standardization work began with the tide of reform and opening-up in the 1980s. The overall developing trend of China building energy efficiency is to develop residential building energy efficiency first, then to develop nonresidential building, and first for the northern area then for the southern area. The JGJ26 "Design standard for energy efficiency of residential buildings in severe cold and cold zones" is very important in China building energy efficiency standard system. This paper briefly reviews energy efficiency standards that have been issued for residential buildings in severe and cold zones in China and development of new version of energy efficiency standards.

# 2 The process of energy efficiency standards for residential buildings in China severe cold and cold zones

The building heating energy in northern China is the major part of the total building energy consumption. Compared with the nonresidential building, the roadmap of building energy efficiency for residential was simple and clear in the 1980s. The JGJ26 "*Design standard for energy efficiency of residential buildings in severe cold* 

<sup>\*</sup> Corresponding author: <u>vzy920801@163.com</u>, <u>chenxi@chinaibee.com</u>

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*and cold zones*" is the first building energy efficiency standard. Since then, building energy efficiency

standards have been developed rapidly, 20 standards are published (see Table 1).

Number	Publish	Nama	Serial
Nulliber	year	Ivane	number
1	1986	Thermal design code for civil building	JGJ24
2	1986	Energy conservation design standard for new heating residential buildings	JGJ26
3	1990	Energy conservation design standard for hotel buildings( provisional)	
4	1993	Thermal design code for civil building	GB50176
5	1993	Standard of climatic regionalization for architecture	GB50178
6	1993	Energy conservation design standard for hotel buildings	GB50189
7	1995	Energy conservation design standard for new heating residential buildings	JGJ26
0	2001	Design standard for energy efficiency of residential buildings in hot summer and cold winter	IG1124
0	2001	zone	JUJ134
9	2003	Design standard for energy efficiency of residential buildings in hot summer and warm	IGI75
,	2005	winter zone	30375
10	2005	Design standard for energy efficiency of public buildings	GB50189
11	2007	Code for acceptance of energy efficient building construction	GB50411
12	2009	Standard for energy efficiency test of residential buildings	JGJ/T132
13	2009	Technical code for the retrofitting of public building on energy efficiency	JGJ/T176
14	2009	Standard for energy efficiency test of public buildings	JGJ/T177
15	2010	Design standard for energy efficiency of residential buildings in severe cold and cold zones	JGJ26
16	2010	Design standard for energy efficiency of residential buildings in hot summer and cold winter	IG1134
10	2010	zone	303134
17	2012	Design standard for energy efficiency of residential buildings in hot summer and warm	IG175
1/	2012	winter zone	10112
18	2012	Technical Specification for Energy Efficiency Renovation of Existing Residential buildings	JGJ/T129
19	2015	Design standard for energy efficiency of public buildings	GB50189
20	2016	Thermal design code for civil building	GB50176

So far, the JGJ26 "Design standard for energy efficiency of residential buildings in severe cold and cold zones" has been revised twice and 3 versions have been published. The process of this standard can be divided into three phases, which also represent the corresponding stages of the building energy efficiency standard system. They are initial stage (1980s-1990s), development stage (1995-2005) and mature stage (2005-now).

### 2.1 Initial stage (1980s-1990s)

From 1986, the first building energy efficiency design standards JGJ 26-1986 "Civil building energy efficiency design standards (residential building heating part)" (short for JGJ 26-86 or JGJ 26-1986) was issued and put into trial use till the revision completed in 1995, this period is the primary work of building energy efficiency Stage [2]. The energy saving rate goal of residential buildings in severe cold and cold areas is 30%, which means that heating energy consumption of new residential buildings should reduce by 30% than the common residential buildings designed in 1980. This is the minimum requirement of building energy efficiency. The main work to fulfill the goal is to promote the thermal performance requirement on building envelope. JGJ 26-1986 is developed based on a large number of investigations and research, domestic and foreign experience. It has Chinese characteristics, such as the statistical method of heating degree days, the application of effective heat transfer coefficient method to estimate heating energy, the design method of heating system, the selection of the boiler, the determination of the pipeline minimum insulation thickness, the requirement of the water transmission coefficient. Compared with the foreign regulations or standards, the level of systematic and scientific is close, but limited to China's technical and economic level, there is a big gap in energy-saving technical measures and the thermal performance requirement of building envelope.

JGJ 26-1986 established the basic idea and methods of China's building energy efficiency design standards, it set a reference residential building designed from 1980 to 1981 (baseline). That means the reference residential building has the typical building structure and the typical energy efficiency of the heating equipment required by the standard to maintain reasonable indoor thermal environment parameters. The energy consumption of this building is a baseline of building energy efficiency standard when calculating the annual heating energy consumption and considered as 100%. Actual building energy consumption are compared with the baseline and exports a relative energy saving rate.

### 2.2 Development stage (1995-2005)

In the initial stage, a lot of basic research work was finished, which provided a foundation for the update of standard. JGJ 26-95 is an upgraded version of JGJ 26-86, whose energy saving rate is 50% [3]. Compared with JGJ 26-86, the energy savings are 30%.

The JGJ 26-95 standard not only improved the envelope thermal performance requirement, but also strengthened the HVAC system energy conservation requirements. Compared with the reference building, there has been a great improvement, but there is still a considerable gap compared with the relevant energy-saving standards of the USA in the world. As an example, the rough concept is that the standard heat transfer coefficient of wall is 2.6 to 3.6 higher than that of the standards in the USA, the roof is 3.2 to 4.2 times higher, the k-value of window is 1.4 to 2 times higher, and the air permeability is 3 to 6 times higher. In other words, the heating energy consumption of residential building designed with JGJ 26-95 is twice higher than the buildings in the USA at the same time [4].

### 2.3 Mature stage (2005-now)

JGJ 26-2010 was released in 2010, and renamed as "design standard for energy efficiency of residential buildings in severe cold and cold zones" [5]. The energy saving rate of JGJ 26-2010 is 65%. Compared with JGJ 26-95, the energy savings are 30%. The requirement of key energy saving measures are closed with developed country with the same climate. This version represented that the energy saving level of residential building energy efficiency standard is similar with that in the USA.

A new calculation method of heat loss index was introduced in JGJ 26-2010, that is an entire envelope thermal performance requirement method. This method gives more freedom for architect in design process. The requirement on line heat transfer coefficient of thermal bridge was also proposed in JGJ 26-2010. This standard made different requirements on shape coefficient and kvalues of building envelopes base on the different number of layers, this is much more easy to use.

# **3** Development of key indices in energy efficiency standards

The three versions of domestic energy efficiency standards mentioned above are compared in key indices to show the development of building performance. The domestic building energy efficiency standards usually include envelope, HVAC systems, pump design and so on, whereas the envelope and HVAC systems are the two most important aspects of energy efficiency standards. So these two aspects are compared. The contemporaneous USA standards are also listed for reference [6]. Beijing is chosen as a typical city located in cold areas of China.

### 3.1 Envelopes

Building envelope is a building structure that surrounds the building heating and cooling zone, including building facades, floors, grounds, roofs, windows and doors, whose thermal performance has a great impact on the building energy consumption. The envelope elements contain roofs, external walls, floors, windows and so on. Their heat transfer coefficients are required in the standard.

In the 3 domestic standards, constraints of the same element may be ruled by different methods. For example, the maximum k-value of external wall in JGJ 26-86 is divided by the building shape coefficient, window type and direction, in JGJ 26-95 the direction is no longer thought about. While in more recent JGJ 26-2010, the floor numbers of building is the only concerned factor. For example, with the reduction of the number of storey of building, the requirement of external wall k-value will be increased. Considering such differences, a typical building with identical parameters is supposed to put everything on the same level in the comparison. We assumed a 10-storey building with a shape coefficient of 0.25, a window-wall ratio of 0.3 in all directions. The windows are all double-glassed with a single metal frame.

ASHRAE 90.1-2010 is referred to as a representative of USA standards. According to its climate classification method, Beijing belongs to the Climate Zone 4C with a heat degree-day between 2000 and 3000. Besides, we suppose that the roof insulation is entirely above deck, the walls are massive, the vertical glazing satisfied the requirement for metal framing windows in curtain wall, and the opaque doors are swinging. The corresponding building envelope requirement is listed in the last column of Table 2.

Table 2. Building envelope requirement for residential	in
Beijing in different standards	

	Heat transfer coefficient (W/(m <sup>2</sup> •K))				
Elements	JGJ	JGJ	JGJ 26-	ASHRAE	
	26-86	26-95	2010	90.1-2010	
Roofs	0.91	0.80	0.45	0.273	
External Walls	1.28	1.16	0.70	0.513	
Core board of lower balcony door	1.72	1.70	1.70	\	
Peripheral Ground	0.52	0.52	١	\	
Non-peripheral Ground	0.30	0.30	\	\	
Partition walls of non-heat room	1.83	1.83	1.50	0.513	
Doors of non- heat room	2.91	2.00	2.00	3.975	

Outdoor air contact floor- slabs	١	0.50	0.60	0.420
Roofs of non- heat basement	١	0.55	0.65	0.420
External	6.40	4.00	2.80	2.84
windows				

In general, the requirement of envelope is raised. The ground insulation is no longer required in JGJ 26-2010 and ASHRAE standard because this is not that significant for a high-rise building. Besides, it is found that the requirement of outdoor air contact floor and roofs of non-



heat basement is lower in JGJ 26-2010 than former standards. In fact, the JGJ 26-2010 standard divided these two requirements by layer number while the former standards regulate all buildings with the same value, corresponding requirements for a low-rise building in JGJ 26-2010 is higher than the former ones. This can also be seen as an advantage of the new standard.

Thermal resistance of roofs, external walls and windows indicates the insulation performance of a building. Fig.1 shows the varied levels of such performance among the standards. Table 3 gives out detailed value and ratio of resistances in the specific Chinese standards to resistances in the US standards.



Fig. 1. Minimum thermal resistance of roofs, external walls (left) and external windows (right) in the 4 standards.

Table 3. Minimum Thermal resistance of external envelopes and relative difference of each standard

Elements	Thermal resistance( (m <sup>2</sup> •K)/W)						
	JGJ 26- 86	Ratio of resistances <sup>a</sup>	JGJ 26- 95	Ratio of resistances	JGJ 26- 2010	Ratio of resistances	ASHRAE 90.1- 2010
Roofs	1.099	30.0%	1.250	34.1%	2.222	60.7%	3.663
External Walls	0.781	40.1%	0.862	44.2%	1.429	73.3%	1.949
External Windows	0.156	44.4%	0.250	71.0%	0.357	101.4%	0.352

a. Ratio of resistances in the specific Chinese standard to resistances in the US standard

Table 4. Minimum design efficiency for coal-fired boiler required by 3 Chinese standards

<b>D</b> . 1 (MMV)	Coal-fired boiler efficiency (%)				
Boller capacity(NIW)	JGJ 26-86 JGJ 26-95		JGJ 26-2010		
0.7	62	\	\		
1.4	70	\	\		
2.8	72	72	73		
4.2	72	73	74		
7.0	74	74	78		
14.0	\	76	79		
>28.0	\	78	80		

Table 5. Minimum design efficiency for oil-fired boiler required by JGJ 26-2010 and ASHRAE 90.1-2010

	Oil-fired boiler efficiency (%)			
Boller capacity(NIW)	JGJ 26-2010	ASHRAE 90.1-2010		
0.7	86	78		
1.4	87	02		
2.8	87	83		

4.2	88	
7.0	89	
14.0	90	
>28.0	90	

The comparison between 3 Chinese standards show a consistent development over the last 20 years, but in performance of roofs and external walls, the requirement is still lower than the contemporaneous USA standard. The requirement of external window of last 2 standards is almost the same.

### 3.2 HVAC Systems

In cold areas, buildings are heat dominated, so we choose the key performance index of heat system to represent the requirement level for HVAC systems in each standard. The coal-fired boiler is the traditional heating mode of cold areas, whose efficiency indicate the transmission rate of energy and is regulated by the standard. Therefore, the minimum design efficiency of coal-fired boiler required in standards is compared. The coal type is set to bituminous coal II. Different capacity of boiler are listed in Table 4.

In ASHRAE standard, there are only requirements for gas- and oil-fired boilers, which is not included in the JGJ 26-86 and JGJ 26-95, so we compare it with JGJ 26-2010 in Table 5.

## 4 Conclusion

China's residential buildings energy efficiency standardization work started from the 1980s and has developed for 30 years. In this paper, the 3 editions of standards used before are reviewed and key indices are compared. The conclusions are as follows:

1) The first energy efficiency standard of China was proposed in 1986 and went through a rapid development since then. After several revisions, the energy consumption reduction percentage has raised from 30% of first JGJ 26-86 to 65% of the JGJ 26-2010. The insulation performance of roofs and external walls increased respectively by 103% and 83%, and the window performance increased by 130%.

2) The building energy efficiency standardization work started late in our country. The gap of energy efficiency requirement in standards between china and the USA still exist and it is gradually narrowing. When it comes to the requirement for external window and oil-fired boiler efficiency, the domestic standard is even higher.

3) The urban-rural residential construction outline in 13<sup>th</sup> five-year plan has proposed that, by 2020, the newly-developed building energy efficiency requirement of implemented standard should increase by 20% compared to the end of 12<sup>th</sup> five-year period [7]. To fulfill the goal, JGJ 26 "*Design standard for energy efficiency of residential buildings in severe cold and cold zones*" is under a new round of revision, the expected energy saving ratio is 75%. Besides, guideline of ultra-low energy

consumption residential building and technical criteria of nearly zero energy building are both under formulation. In this way, we keep a consistent rise of the mandatory standards for building energy efficiency design, establish technical criteria with higher energy saving performance for guideline and finally fulfill the total amount control of building energy consumption.

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# References

- 1. S. Nadel, The Future of standards, ENERG BUILDINGS **26**(1997):119-128.
- 2. PRC Urban and Rural Construction Environmental Protection Department, *Civil building energy efficiency design standards (residential building heating part)*, (1986).
- 3. PRC Construction Department, *Energy conservation design standard for new heating residential buildings*, (1996).
- 4. S. Lang, Compiling thinking and progress of energy efficiency design standards in buildings in China, HV&AC, **34**(2004):30-36.
- 5. PRC Housing and Urban-rural Development Department, *Design standard for energy efficiency of residential buildings in severe cold and cold zones*, (China Building Industry Press, 2010)
- 6. American Society of Heating, Refrigerating and Airconditioning Engineers, *ANSI/ASHRAE/IES Standard 90.1-2010. Energy standard for buildings except low-rise residential buildings.* (Atlanta: ASHRAE, 2010)
- PRC Housing and Urban-rural Development Department, 13<sup>th</sup> five-year plan for building energy conservation and development of green buildings, (2017)