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Title

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Publication Date

2003-07-01

An Energy Standard for Residential Buildings in South China

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Keywords: residential, buildings, energy standard, energy design, South China

Abstract: To curb the spiraling demand for building energy use, China's Ministry of Construction has worked at developing and implementing building energy standards, starting with a standard for heated residential buildings in the Cold regions in 1986, followed by a standard for residential buildings in the Hot Summer Cold Winter Region in central China in 2001. In July 2001, a similar effort was started to develop a standard for residential buildings in the Hot Summer Warm Winter Region, comprising of the entirety or large portions of Guangdong, Guangxi, Hainan and Fujian. The target for the standard is to improve the thermal efficiency of buildings by 50% compared to current construction, which are typically uninsulated and have single-pane windows. Because of the importance of controlling window solar gain, the standard developed tables specifying the required window thermal transmittance and shading coefficient for differing window-to-wall ratios. The intent of such trade-off table is to permit flexibility in the location and size of windows, as long as their thermal performances meet the requirements of the standard. For further flexibility, the standard provides three methods of compliance: (1) a simple set of prescriptive requirements, (2) a simplified performance calculation, and (3) a detailed computer-based performance calculation using a Custom Budget approach.

1 INTRODUCTION

Since the liberalization of the economy starting in the late 1980s, China has witnessed dramatic increases in both the rate of building construction, and the energy used to heat and cool buildings. Comparing to 1984, the floor area of new construction has increased by almost ten times, from 138 to 1321 million m^2 per year (CSP 1985, 2001). Over the same time period, building energy use intensity in W/m^2 has also increased, especially in central and south China where there has been a dramatic growth in air conditioning. Because of these compounding effects, the energy consumed by the building sector is estimated to have increased from 10% in 1978 to 27% in 2001 of an expanding national energy budget.

To counter this spiraling rise in building energy use, the Ministry of Construction (MOC) has been developing and implementing building energy standards since the mid-1980s. Because of the tremendous variation in climates within China, the MOC delineated five climate regions - Severe Cold, Cold, Hot Summer Cold Winter, Hot Summer Warm Winter, and Transition. The first two regions are also known collectively as the Heating Zone where heating is required by law.

Prior to 1990, residential buildings in these two regions were the only ones that used large amounts of energy for space conditioning. Therefore, the first MOC effort in building energy standards was the development in 1986 (and revision in 1996) of an "Energy Conservation Design Standard for New Heated Residential Buildings", numbered JGJ 26-86 and 26-95 (MOC 1986, 1996). The energy saving goals of this standard was a 30% reduction in heating energy consumption compared to standard 1980's construction by Stage 1 in 1986 and a 50% reduction by Stage 2 in 1996.

From March 2000 to September 2001, two of the co-authors (Lang and Lin) chaired a Code Compilation Committee to develop a residential building energy standard for the Hot Summer Cold Winter (HSCW) region in central China, while the other two co-authors (Huang and Hogan) provided technical support and suggestions based on experiences in the US (Hogan et al. 2001). This standard, titled, "Energy Efficiency Design Standard for Residential Buildings in the Hot Summer Cold Winter Region", was submitted to the MOC in August 2001 and adopted in October 2001 as JGJ 134-2001 (MOC 2001).

Due to the need to consider cooling as well as heating energy use, the DOE-2.1E computer simulation program (Winkelmann et al. 1993) was used to set the energy conservation requirements of the building energy standard. Led by Lin, the Compilation Committee used DOE-2 to analyze the energy performance of different building options in the major cities within the HSCW Region, and arrived at a minimum set of prescriptive measures that would reduce the total energy used for heating and cooling by 50% compared to the existing building practice of uninsulated concrete or masonry construction and single-pane windows with clear glass and metal frames. JGJ 134-2001 also provided two alternate compliance options: (1) a simple set of prescriptive requirements for roof, wall, and window thermal tranmittances, or (2) performance requirements for heating and cooling in W/m^2 based on a location's heating and cooling degree days.

2 DEVELOPMENT OF THE HSWW RESIDENTIAL ENERGY DESIGN STANDARD

In July 2001, as the HSCW standard was nearing completion, the MOC embarked on a similar effort to develop an energy standard for residential buildings in the Hot Summer Warm Winter (HSWW) region, comprising of the entirety or large portions of Guangdong, Guangxi, Hainan and Fujian (see Figure 1). The procedure used in developing the HSWW standard was very similar to that used before in developing the HSCW standard. Under the aegis of the MOC, a Code Compilation Committee was formed including building researchers and officials from each of the provinces and autonomous region or major cities in the region, energy experts and MOC officials from Beijing, and interested industry representatives. The Committee was again chaired by Lang and Lin, with key contributions by researchers from the Guangdong Academy of Building Research, Guangzhou Building Research Institute, and the Fujian Academy of Building Research.

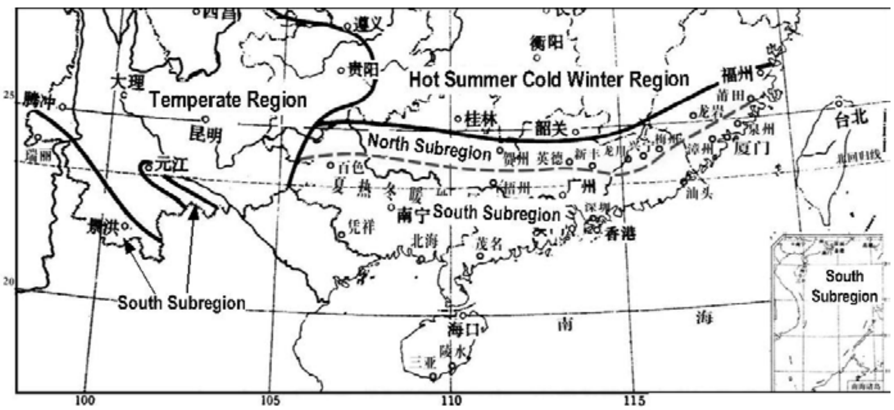

Figure 1. Map of the Hot Summer Warm Winter Region

Domestically, the MOC provided support for the research activities of the Committee. Internationally, the US Energy Foundation provided support to both the Committee and to Huang and Hogan. Between the kick-off meeting held in Conghua, Guangdong, in July 2001 and the final Expert's Review meeting held in Fuzhou in March 2003, the Committee held a total of four working meetings, each lasting one to two days. The draft standard was approved at the March 2003 Expert's Review, and submitted to the MOC in May 2003 for approval and printing.

3 OBJECTIVES OF THE STANDARD

Despite initial reservations whether such a target was achievable, the Committee agreed to maintain the same energy conservation target as in the previous MOC standards of a 50% reduction in space conditioning energy use compared to current construction, which were typically of uninsulated masonry with single-pane windows with metal frames and clear glass. Since air conditioners in south China are still operated manually, this 50% target should best be regarded as a 100% improvement in energy efficiency, split roughly between improvements to the building shell and the space conditioning equipment.

The climate in the HSWW region is characterized by long summers that are hot and humid, with short winters that are mild and short. Based on a study of average winter temperatures, the Committee decided to divide the HSWW region into two subregions – a narrow North Subregion where heating is needed during the winter, and a larger South Subregion where heating is not needed (see Figure 1). For the energy standard, heating energy use is considered only in the North Subregion, and ignored for the South Subregion.

4 STRUCTURE OF THE STANDARD

Building on the experiences gained in developing the HSCW standard and review of international building energy standards, the Committee designed the HSWW standard with three alternate methods of compliance: (1) a simple set of prescriptive requirements with tables of allowable combinations of window area, thermal transmittance, and solar heat gain, (2) a simple performance method with regression equations to estimate the energy budget of different building designs, and (3) a computer-based performance method using the DOE-2 computer program. Both performance calculations follow the Custom Budget Method that varies the performance index with the size and geometry of the candidate building. This use of the Custom Budget Method is new to China, but has been found effective in US standards such as ASHRAE 90.1 or California's Title-24.

The overall outline of the standard is similar to that of the HSCW standard and consists of 6 sections and 3 appendices. Section 1 describes the basic principles of the standard, while Section 2 gives definitions for such new terms as the *Custom Budget Method, Reference Building, Annual Cooling and Heating Energy Electricity Consumption (EC),* etc.

Section 3 defines the assumed indoor conditions under which the calculations of heating and cooling energy use are made: 26°C for cooling and 16°C for heating (in the Northern Subregion only) at all hours, and an infiltration rate of 1 air-change per hour. These indoor conditions are not necessarily those found in typical residences in the HSWW region, but provide an objective basis upon which to evaluate the energy performance of different building designs and energy measures.

Section 4 describes the prescriptive requirements for the building shell. In the HSWW climate, the greatest source of heat gain is solar radiation striking the surfaces or entering through the windows, rather than heat conduction through the walls and roof. Consequently, the thermal transmittance requirements for the roof and walls are quite modest and simple (see Table 1), but window solar gain is controlled by two requirements: (1) the Window-to-Wall Ratio (WWR) is limited to 0.50 facing south, 0.45 facing north, and 0.30 facing east and west, and (2) tables of allowable combinations of window Shading Coefficient (SC) and thermal transmittance, depending on wall type and WWR (see Tables 2 and 3). These tables permit flexibility in the design of windows by allowing architects to compensate for larger window areas by making the windows better shaded, using glass with a lower SC, or , in the North Subregion, reducing the window thermal transmittance.

Table 1 Thermal Transmission Coefficient ($K= W/m^2K$) and Thermal Inertia Index (D) for the Roof and Exterior Walls

Roofs	Exterior Walls
$K \leq 1.0$, $D \geq 2.5$	$K \leq 2.0$, $D \geq 3.0$ or $K \leq 1.5$, $D \geq 3.0$ or $K \leq 1.0$, $D \geq 2.5$
$K \leq 0.5$*	$K \leq 0.7$*

* D < 2.5 is considered a light-construction roof or exterior wall and must also meet the thermal insulation requirements of the national standard "Thermal design of civil construction" (GB 50176-93).

Table 2 Allowable Thermal Transmission Coefficient and Overall Shading Coefficients for Residential Buildings in the North Subregion

Exterior wall	Overall Window Shading Coeff. *Sw*	Thermal transmission coefficient of exterior window $K= W/(m^2 \cdot K)$				
		Avg WWR $C_M \leq 0.25$	Avg WWR $0.25<C_M \leq 0.3$	Avg WWR $0.3<C_M \leq 0.35$	Avg WWR $0.35<C_M \leq 0.4$	Avg WWR $0.4<C_M \leq 0.45$
$K \leq 2.0$ $D \geq 3.0$	0.9	≤ 2.0	------	------	------	------
	0.8	≤ 2.5	------	------	------	------
	0.7	≤ 2.5	≤ 2.0	≤ 2.0	------	------
	0.6	≤ 3.0	≤ 2.5	≤ 2.5	≤ 2.0	------
	0.5	≤ 3.5	≤ 2.5	≤ 2.5	≤ 2.0	≤ 2.0
	0.4	≤ 3.5	≤ 3.0	≤ 3.0	≤ 2.5	≤ 2.5
	0.3	≤ 4.0	≤ 3.0	≤ 3.0	≤ 2.5	≤ 2.5
	0.2	≤ 4.0	≤ 3.5	≤ 3.0	≤ 3.0	≤ 3.0
$K \leq 1.5$ $D \geq 3.0$	0.9	≤ 5.0	≤ 3.5	≤ 2.5	------	------
	0.8	≤ 5.5	≤ 4.0	≤ 2.5	≤ 2.0	------
	0.7	≤ 6.0	≤ 4.5	≤ 3.5	≤ 2.5	≤ 2.0
	0.6	≤ 6.5	≤ 5.0	≤ 4.0	≤ 2.5	≤ 3.0
	0.5	≤ 6.5	≤ 5.0	≤ 4.5	≤ 3.5	≤ 3.5
	0.4	≤ 6.5	≤ 5.5	≤ 4.5	≤ 4.0	≤ 3.5
	0.3	≤ 6.5	≤ 5.5	≤ 5.0	≤ 4.0	≤ 4.0
	0.2	≤ 6.5	≤ 6.0	≤ 5.0	≤ 4.0	≤ 4.0
$K \leq 1.0$ $D \geq 2.5$ or $K \leq 0.7$	0.9	≤ 6.5	≤ 6.5	≤ 4.0	≤ 2.5	------
	0.8	≤ 6.5	≤ 6.5	≤ 5.0	≤ 2.5	≤ 2.5
	0.7	≤ 6.5	≤ 6.5	≤ 5.5	≤ 4.5	≤ 2.5
	0.6	≤ 6.5	≤ 6.5	≤ 6.0	≤ 5.0	≤ 4.0
	0.5	≤ 6.5	≤ 6.5	≤ 6.5	≤ 5.0	≤ 4.5
	0.4	≤ 6.5	≤ 6.5	≤ 6.5	≤ 5.5	≤ 5.0
	0.3	≤ 6.5	≤ 6.5	≤ 6.5	≤ 5.5	≤ 5.0
	0.2	≤ 6.5	≤ 6.5	≤ 6.5	≤ 6.0	≤ 5.5

Section 5 explains the Custom Budget Method to meet the performance requirement of the standard. The Custom Budget Method defines a hypothetical Reference Building having the same size and other characteristics as the candidate building, and uses the hypothetical building to calculate a "custom" energy budget using one of the two calculation methods approved by the standard. The calculation is then repeated

Table 3 Allowable Overall Shading Coefficients of Windows for Residential Buildings in the South Subregion

Exterior walls (Solar absorp. $\rho \leq 0.8$)	Overall shading coefficient of window system (S_{WP})				
	Avg WWR $C_M \leq 0.25$	Avg WWR $0.25 < C_M \leq 0.3$	Avg WWR $0.3 < C_M \leq 0.35$	Avg WWR $0.35 < C_M \leq 0.4$	Avg WWR $0.4 < C_M \leq 0.45$
$K \leq 1.5$, $D \geq 3.0$	≤ 0.8	≤ 0.7	≤ 0.6	≤ 0.5	≤ 0.4
$K \leq 1.0$, $D \geq 2.5$ or $K \leq 0.7$	≤ 0.9	≤ 0.8	≤ 0.7	≤ 0.6	≤ 0.5

notes 1. WWRs apply to both windows and glazed portions of balconies.
2. Thermal transmission coefficient requirements for exterior windows are not defined for the South Subregion.

for the candidate building, whose energy budget must be lower than the Custom Budget in order to comply to the standard. The Custom Budget Method has been used successfully in various US building energy standards because it can adjust the energy budget for the effects of building size and other characteristics that a standard wishes to keep neutral.

Clearly, the Reference Building needs to be defined clearly and carefully for the Custom Budget Method to have its intended purpose of providing flexibility without downgrading building energy performance. In the current draft, the Reference Building is defined as having the same architectural shape, size, and orientation as the candidate building, but the WWR must be kept within the restrictions of Section 4. This means that the Custom Budget Method penalizes a design for having excessive amounts of windows, but not for a convoluted building shape. An alternative would be to limit the Reference Building to the same Shape Factor, i.e., surface-to-volume, limits as stated in Section 4. Further study will be needed to determine the impact of how the Reference Building is defined and whether any modification is warranted.

Section 5 describes two calculation methods for applying the Custom Budget Method. The first is a simplified calculation described in Appendix A and B based on regression results from the DOE-2 simulations. The other method is to actually make DOE-2 simulations based on the modeling assumptions in Section 3 and the rules for generating the Reference Building in Section 5. Since this would be extremely time-consuming and difficult for a typical user, Lin is now developing an easy-to-use software package for doing this. This software package builds on previous work that produced a software tool for the HSCW standard which used a Fixed Budget Method.

Section 6 give recommendations on the selection of the space conditioning equipment. Since in the Chinese housing market the developers typically sell the apartments unfurnished, and the space conditioning equipment are purchased by the apartment owners, it is difficult to enforce the use of energy-efficient equipment through building energy standards. Section 6 recommends the use of equipment meeting the standards developed by the China Certification Center for Energy Conservation Products (CECP), and provides guidelines on correct installation to ensure energy efficient operations. For the North Subregion, the standard strongly discourages the use of electric resistance heating in all but a few special cases.

5 PRACTICAL ISSUES RELATED TO THE STANDARD

During the development of the standard, a number of practical issues were identified that would affect the implementation of the standard. The Standard allows trade-offs between window solar gain, thermal transmission, and WWR, but there is no standardized method of test on the solar heat gain characteristics of window products. Therefore, designers may find it difficult to obtain reliable and accurate SCs to use in Tables 2 and 3, or the performance calculations. In partial response to this problem, the authors are involved in a US Energy Foundation-supported project with the MOC to establish energy test procedures and labels for windows. A similar problem exists with respect to the standard's recommendation to use paints or surfacing materials with absorptivities under 0.40 on walls and roofs, but there is very little such technical information in the marketplace.

6 COMPARISON OF STANDARD TO OTHER STANDARDS IN SIMILAR CLIMATES

For a similar climate to the HSWW region, the ASHRAE 90.1-1999 requirements for residential buildings are comparable for exterior walls, but nearly three times lower for the roof, as compared to the HSWW standard. ASHRAE 90.1 requires only single-pane windows, but their Solar Heat Gain Coefficients (SHGC) must be less than 0.40 (0.61 for north-facing), equivalent to SCs of 0.46 and 0.70. The Florida code has somewhat lower requirements for masonry walls, but even more stringent requirements for roofs, although it must be pointed out that these are light-weight wood-framed roof./ceiling assemblies. For windows, the Florida code allows double-pane clear glass if the Window-to-Floor Ratio (WFR) is less than 20% but tinted glass must be used if the WFR is up to 25% (see Table 4). Typical SCs for such windows are 0.88 for clear and from 0.56 to 0.72 for tinted glass.

7 CONCLUSIONS

The HSWW standard is an improvement over earlier Chinese building energy standards in its flexibility and accuracy through using a simulation-based Custom Budget Method. The prescriptive requirements are somewhat more lenient but not overly so compared to those in US standards in comparable climates, and in many cases reflect realistic assessments of product availability in the marketplace. If the standard is rigorously implemented , it will have a significant impact in reducing the

Table 4 Thermal Properties in US Standards for Similar Climates

Standard and Region	HDD 18ºC	CDD 10ºC	Roof conductance W/(m² K)		Exterior wall conductance W/(m² K)		Window conductance K W/(m² K) and SHGC
ASHRAE 90.1-1999			*No attic*	*Attic*	*Mass*	*Wd frame*	
Table B-3	0-500	4000-5000	0.35	0.15	0.86	0.50	K-6.9-7.2; SHGC 0.61 north/ 0.40 other if WWR <0.40, 0.47 north/ 0.31 if 0.4 <WWR≤0.50
Florida State code					*Masonry*	*Wd frame*	
Miami	89	5351	0.19	0.19	1.13	0.52	<20%WFR double clear <25% WFR double tint

energy waste in high-rise glass boxes with uncontrolled solar heat gain. The implementation of building energy standards in China, however, has always been problematic, and hampered by a weak and ill-defined enforcement infrastructure. Whereas in many states in the US building energy regulation has approached that of structural and fire inspection in thoroughness, in the regions of China where building energy standards have been in place, their enforcement is still haphazard and often regarded as more than an expression of good intentions. It is hoped that through a combination of improved building standards, better implementation, voluntary programs to promote energy-efficient construction, and heightened public awareness of their benefits to the consumer, China will be able to transform its construction industry from quantity to quality.

REFERENCES

CSP 1985, 2000. China Statistical Yearbook (中国统计年鉴) 1985, 2000, China Statistics Press, Beijing, China.

Hogan, J., Watson, R., Huang, Y.J., Lang, S.W., Fu, X.Z., and Lin, H.Y. 2001. "Development of China's Transition Zone Energy Code for Residential Buildings", *Third International Conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings*, Changsha, China.

MOC 1986, 1996, "Energy Conservation Design Standard for New Heated Residential Buildings (民用建筑节能设计标准（采暖居住建筑部分））", JGJ26-86, JGJ 26-95, Ministry of Construction, Beijing, China.

MOC 2001, "Energy Conservation Design Standard for Residential Buildings in the Hot Summer Cold Winter Region (夏热冬冷地区建筑节能设计标准)", JGJ 134-2001, Ministry of Construction, Beijing, China.

Winkelmann, F.C., Birdsall, B.E., Buhl, W.F., Ellington, K.L., Erdem, A.E., Hirsch, J.J., and Gates, S. 1993, "DOE-2 Supplement, Version 2.1E", LBL-234949, Lawrence Berkeley Laboratory, Berkeley CA, USA.