Summarization of Energy efficiency in buildings in West China

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Abstract: according to the different climatic characters of the different regions in West China, combining with energy efficiency in buildings (EEB) standards and local resources, this paper discussed the technologies of EEB applicable in the representative cities of freezing, cold, hot-summer and cold-winter, warm regions. The author explored the keystones of the EEB technologies' development, but hasn't recommended technology of EEB concretely.

Keywords: West China; representative city; EEB

1. Introduction

West China has a wide land and can be divided into freezing region, cold region, hot-summer and cold-winter region, and warm region. Because of the different climatic and resource conditions, the keystones of energy efficiency in buildings technologies (TEEB) in different climatic regions are different. This paper explored TEEB applicable in different climatic regions of west China. The abbreviations used in this paper are as follows.

EEB: Energy efficiency in buildings;
TEEB: Technologies of energy efficiency in buildings;
DR: Daily range;
AMT: Annually mean temperature;
HODT: Heating outdoor design air temperature;
VODT: Ventilation outdoor design air temperature;
SDMTR: Summer daily maximum temperature range;
AODWT: air-conditioning outdoor design wet- bulb temperature;
SOMAV: Summer outdoor mean air velocity;
WOMAV: Winter outdoor mean air velocity;
WPPS: Winter percentage of possible sunshine;
REC: Ration of electricity consumption;
RHC: Ration of heat consumption;
RCC: Ration of coal consumption;
K_r: Coefficient of heat transfer of roof;;
K_{wa}: Coefficient of heat transfer of external wall;
K_{wi}: Coefficient of heat transfer of external window;
HDD: Heating degree day;
CDD: Air-conditioning degree day.

2. TEEB in freezing region

The freezing region includes north and south of Xinjiang province, north of Tibet, Qinghai province, and Neimeng province. The mean temperature of coldest month is less than −10℃ , there are more than 145 d that DR less than −5℃.Take the cities of Wulumuqi and Xining as the representative cities of the freezing region. The climatic characters are listed in Table 1.

Table 1. Climatic characters of freezing region

City	AMT /℃	HODT /℃	VODT /℃	SDMTR /℃	AODWT /℃	SOMAV /(m/s)	WOMAV /(m/s)	WPPS /%
Wulumuqi	5.7	-22	29	9.8	18.5	3.1	1.7	50
Xining	5.7	-13	22	10.0	16.4	1.9	1.7	70

The parameters of AMT, SDMTR, and WOMAV are almost the same for two cities. However, the temperature difference of winter and summer in Wulumuqi is so great. The sunshine of Wulumuqi is lower than that of Xining in winter, but higher in summer. Not only need heating in winter, but also need cooling in summer. Xining need only heating in winter, the VODT of 22 ℃ falling into the comfortable temperature zone, need not energy consumed to maintain the indoor comfort. EEB design parameters

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for Wulumuqi and Xining are listed in Table 2.

Table 2. EEB design ration for freezing region

City	RHC /(W/m^2)	RCC /(W/m^2)	K_r /(W/m^2)	K_{wa} /(W/m^2)	K_{wi} /(W/m^2)
Wulumuqi	21.8	17.0	≤0.50	≤0.56	≤2.50
Xining	20.9	16.3	0.70	0.68	4.00

Remark: figure-factor corresponding the coefficients of heat transfer of table 2 is ≤0.3.

The climatic characters of Wulumuqi make the TEEB is mainly for winter, but summer can't be ignored. The roof and external wall satisfying the qualities in table 2 are over-costly for house-buyers to afford if the building envelopes were heat-insulated by common material. The dry climate of Wulumuqi make building envelopes feasible to use the material of air-containing concrete with air interlayer be interlined. What's more, windows of high-energy efficient used in East *China* or overseas can be introduced into Wulumuqi. The key technology of heating in winter is the optimization and adjustment of radiator, pipenet and pumps, to get the objective of measure by families and adjust by rooms. With the high SDMTR and SOMAV, the technology of intermittent ventilation can be adopted in summer to reduce energy consumption.

As utilization of new energies, Xinjiang can't depend on solar energy solely with the 50% WPPS and -22℃ of HODT. It can consider ground-source heat pump to help solar heating, which can deposited heat energy in summer cooling, or intensifying the heat exchange of soil or improve the depth of under-ground heat exchanger to improve the heating capacity.

TEEB of Xining is almost the same type as that of Wulumuqi. However, the summer climate of Xining is so comfortable that only natural ventilation technology need to be used. The HODT of Xining is 9℃ higher than that of Wulumuqi, WPPS is 20% more. So solar heating technology can be utilized to assure inhabitants' comfit. The keystone of solar heating technology is the incorporation of solar energy collector, solar energy accumulator into building designing, which brings challenge and opportunity for the designers.

3. TEEB in cold region

Cold region includes east of Gansu province, north of Shanxi province, middle of Xinjiang province, south of Tibet, west of Sichuan province. The mean temperature of coldest month is 0 -10℃ , there are 90~145 days that DR less than 5℃ .Take the cities of Xi'an and Lanzhou as the representative cities of the cold region. The climatic characters are listed in table 3.

Table 3. Climatic characters of cold region

City	AMT /℃	HODT /℃	VODT /℃	SDMTR /℃	AODWT /℃	SOMAV /(m/s)	WOMAV /(m/s)	WPPS /%
Xi'an	13.3	-5	31.0	8.7	26.0	2.2	1.8	43
Lanzhou	9.1	-11	26.0	9.0	20.0	1.3	0.5	61

The temperature of Xi'an is higher than that of Lanzhou, however, WPPS is 18% less than that in Lanzhou. The summer VODT of 31℃ is beyond the comfortable temperature zone . Xi'an needs cooling in summer and heating in winter. Lanzhou need heating in winter ,but needn't cooling in summer for 26℃ of VODT, falling in the comfortable temperature zone. EEB design parameters for Xi'an and Lanzhou are listed in table 4.

Table 4. EEB design ration for cold region

City	RHC /(W/m^2)	RCC /(W/m^2)	K_r /(W/m^2)	K_{wa} /(W/m^2)	K_{wi} /(W/m^2)
Xi'an	20.2	9.7	≤0.8	≤1.28	≤4.00
Lanzhou	20.8	13.2	0.7	1.10	4.00

Remark: figure-factor corresponding the coefficients of heat transfer of table 4 is ≤0.3.

Xi'an has a relative high level of economy, so the main material of wall and roof, the energy efficient windows, doors and hardwires, all can develop towards top grade, which can bring better results in EEB. The heating system that satisfying the requirement of measure by house and adjustment by room should be developed too. The radiator in the bi-pipe systems can increase the resistance to improve the balance performance and heat release capacity, still can lessen radiator's volume. Xi'an needs cooling in summer. Natural ventilation can be used by the character of high SOMAV(2.2m/s) in nights and low temperature(26.5℃).The ventilation in summer nights should maintain a good air organization to avoid blowing on the sleeping

bodies with consideration of building figure-factor and area ratio of window-to-wall. At the same time, sunshine shielding of windows in summer should be paid attention to, which can use the technology and products of mobile window applied in the east region of hot-summer and cold-winter or hot-summer and warm-winter region.

The emphasis of EEB in Lanzhou is winter heating. Besides the common heat insulation of external wall, the key TEEB, which can be developed mainly, is solar heating technology. There is an abundant sunshine of 61% WPPS, while only 0.5m/s WOMAV, which is in favor of solar house application. The keystone of solar heating technology has been mentioned before. There is not any difficult in Lanzhou EEB in summer, with only attention to natural ventilation and window's sunshine shielding.

4. TEEB in hot-summer and cold-winter region

Hot-summer and cold-winter region includes Chongqing, east of Sichuan province, east of Guizhou province, west of Shanxi province. The mean temperature of hottest month in this region is 25~30℃ with 0~10℃ in the coldest month. the days that DR more than 25℃ is 40~110 days, DR less than 5℃ is 0~90 days. Take the cities of Chengdu and Chongqing as the representative cities of this region, the climatic character are listed in Table 5.

Table 5. Climatic characters of hot-summer and cold-winter region

City	AMT /℃	HODT /℃	VODT /℃	SDMTR /℃	AODWT /℃	SOMAV /(m/s)	WOMAV /(m/s)	WPPS /%
Chongqing	18.3	4	33	7.7	27.3	1.4	1.2	13
Chengdu	16.2	2	29	6.9	26.7	1.1	0.9	21

Compared with the east Yangtze delta, which belong to the same climatic region, the main character in Table 5 is low WOMAV and low WPPS. Chongqing and Chengdu are the cities of least sunshine in China, and the solar attribution asymmetry to time, mainly abundant in summer and slim in winter, which is not favorable for EEB.

There is still difference in the tow cities' climate, mainly in summer. It is continuous fine for many days in Chongqing usually, even at summer nights, air temperature still high and need to be cooled strongly. However, because of the low WPPS, the sol-air temperature is so low that heating is needed to maintain a comfortable environment indoors in winter, although the outdoor air temperature is somewhat high.

It is not hot in Chengdu in summer, whose ventilation temperature only 29℃. But the summer humidity is so great in Chengdu that the mean humidity of hottest month is 85%, which is mostly double as that of Wulumuqi (44%). The common ventilation technology can't assure the comfort and need dehumidifying. It needs also heating in Chengdu as Chongqing in winter.

It has been prescribed in the standard of hot-summer and cold-winter region's EEB design (JGJ134-2001) that the indoor design temperature is 16~18℃ for winter heating and 26~28℃ for summer cooling, air change rate is more than 1.0 time per hour. As the Coefficient of heat transfer K and the thermal inertia D of building envelope, it's been prescribed as : $K \leqslant 1.0, D \geqslant 3.0$ or $K \leqslant 0.8, D \geqslant 2.8$ for the roof ; $K \leqslant 1.5, D \geqslant 3.0$ or $K \leqslant 1.0, D \geqslant 2.5$ for the external walls ; $K \leqslant 3.2$ for windows (the ratio of window area to wall area is 0.30~0.35).

Table 6. EEB design ration for hot-summer and cold-winter region

City	HDD /℃	CDD /℃	RHC /(W/m^2)	RCC /(W/m^2)	REC /(kW·h/m^2)
Chongqing	1073	241	12.3	31.3	47
Chengdu	1454	27	15.4	18.5	39.6

With the hole-tive nonclay brick be used as external walls, still added with a outside heat insulation layer, the roof be heat-insulated or be slopping roof, the window be single-casing and double layers plastic glasses, it can satisfied the requirements of EEB ration in Table 6 and suitable for Chonging's and Chengdu's house-buyers to afford. The TEEB of external building envelope most worthy of developing are virescence of roof and external wall, getting ecological and energy benefits simultaneously, and mobile window sunshine shielding technology.

Chongqing need mechanical ventilation at nights to

intensifying heat release because the high temperature in summer. As the low sunshine in winter while abundant sunshine in summer, the common solar-house technology can't be used to maintain the comfort in winter. The adjustment and utilization technology of season-transcending climatic resource is worthy of developing. It can use the underground rock or clay as heat-accumulator in Chongqing to accumulate solar energy in summer to be used in winter heating, and accumulating cold energy in winter to use in summer cooling, which is the ground-source heat pump hot and cold climatic resource adjustment system. The abundant underground water resource in Chengdu can be used. It needs dehumidifying in summer and heating in winter, but the protection of underground water resource must be considered.

5. TEEB in warm region

Warm region includes Yunnan province, Xichang of Sichuan province, west of Guizhou province. The mean temperature of coldest month in this region is 0~13℃, and 18~25℃ in the hottest month. The days that DR less than 5℃ is 0~90 days. Take the cities of Kunming and Guiyang as the representative cities of the warm region. The climatic characters are listed in Table 7.

Table 7. Climatic characters of warm region

City	AMT /℃	HODT /℃	VODT /℃	SDMTR /℃	AODWT /℃	SOMAV /(m/s)	WOMAV /(m/s)	WPPS /%
Kunming	14.7	3	23	6.9	19.9	1.8	2.5	72
Guiyang	15.3	-1	28	7.1	23.0	2.0	2.2	19

The summer climate characters of the two cities in Table 7 are close, the summer VODT are both in comfortable zone. However, there is a large lag in winter in which Kunming has abundant sunshine of 71% while Guiyang only 19%.

There is no EEB standard for warm region as now in China. It is commonly believed that building consumed energy of warm region is not high and need not to be prescribed in the EEB standards. With the development of social economy, the phenomena of environment deterioration caused by energy waste in buildings can be expected to appear if the EEB in warm region was not regarded seriously.

The basic conception of EEB in warm region is to utilize the favorable climatic resource as much as possible to better the thermal condition indoors. The keystone of summer EEB is to develop natural ventilation technology not only for the residential buildings but also for the commercial buildings. An applicable technology for commercial building to avoid using mechanical refrigeration is sunshine shielding of window. Kunming can using solar heating and develop the technology of solar house, while Guiyang can use the technology used in Chongqing and Chengdu of season-transcending climatic resource adjustment system (ground-source heat pump) for reference.

6. Conclusion

The basic conception of TEEB in the west China is economic, harmless to environment, utilization of local resource as much as possible. Some keystone technologies can be introduced from the east of China or abroad. Great effort should make to compose the technology system of TEEB, forming distinct character of the west China.

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