SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

中国建研院 环境能源研究院
Institute of Building Environment and Energy

EET 环能科技

Standard Introduction for Zero Carbon Buildings in China

CAI Wenbo, CABR, 10th Oct. 2023, Graz

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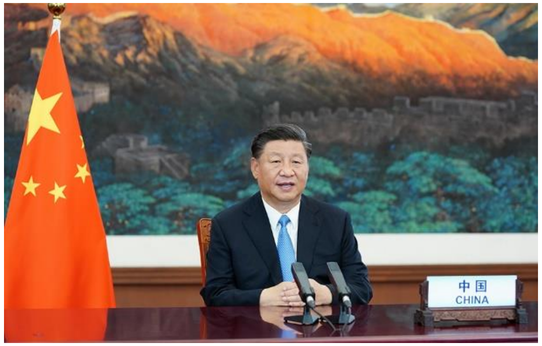
Background

Building energy efficiency is the key to China's low-carbon development

- **Carbon peak and neutrality targets**

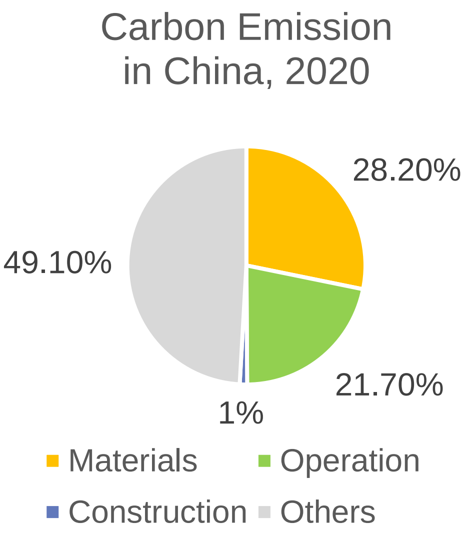


The climate change has become the global focus. In 2020, China proposed "Carbon Peak and Neutrality Target" and highlights the willingness to take effective policies and measures to achieve green and low-carbon development.

- **Carbon emission in building field**

The greenhouse gas is the direct product from the burning of fossil fuels. According to the UNEP, building industry accounts for 34% of global energy consumption.

In China, operation and construction of buildings account for 50.9% of social carbon emission.



Standards

- **JGJ 26-1986——"Design standard for energy efficiency of residential buildings (Heating residential buildings part)"**

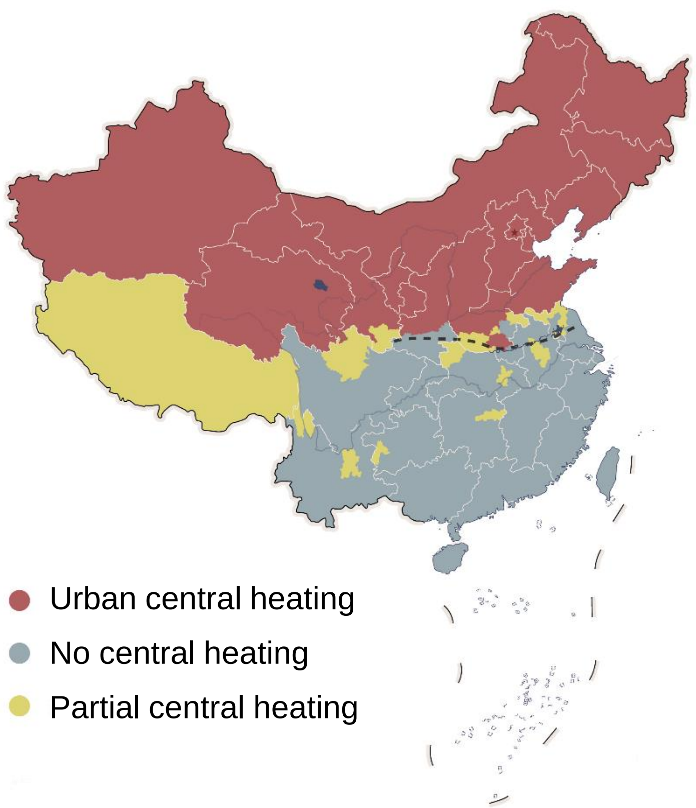
✓ The first building energy efficiency standard in China;

✓ 30% reduction of building energy consumption from the 1980-1981 level;

- **JGJ 26-1995——"Design standard for energy efficiency of residential buildings"**

✓ A further 30% reduction based on JGJ 26-1986, and achieve 50% building energy saving rate;

Central heating map in China

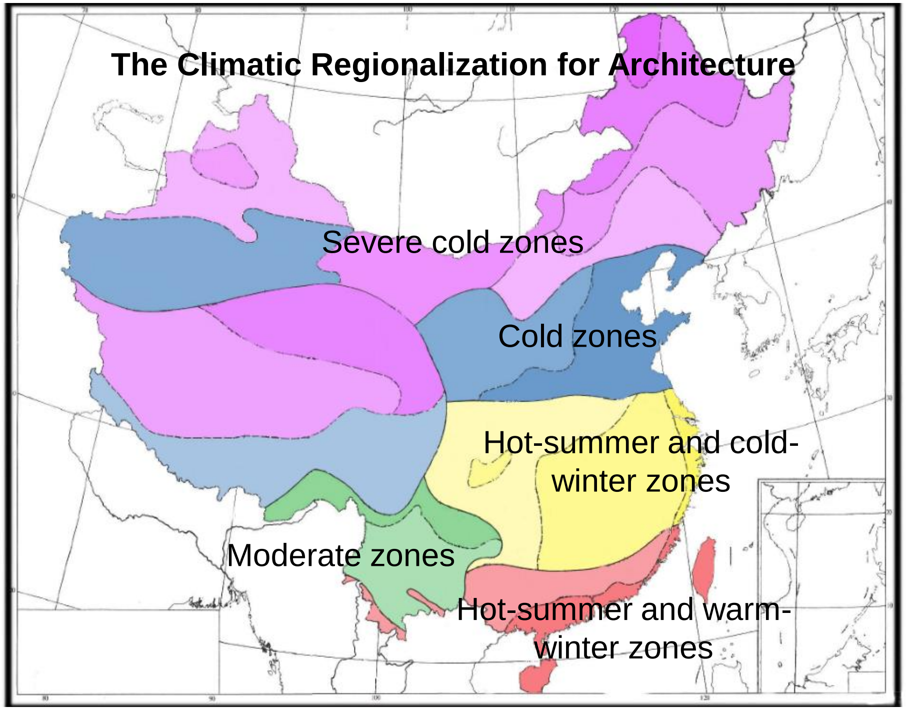


Standards

- **GB 50176-1993——"Code for thermal design of civil building"** (Has been replaced by 2016 version)

- **GB 50178-1993——"Standard of climatic regionalization for architecture"**

✓ Dividing China into 5 primary zones and 11 secondary zones of climate for building design;



Zones	Indicators		Design principles
	Primary	Secondary	
Severe cold zone	$t_{min \cdot m} \leqslant -10℃$	$145 \leqslant d_{\leqslant 5}$	The heat preservation in winter must be considered
Cold zone	$-10℃ < t_{min \cdot m} \leqslant 0℃$	$90 \leqslant d_{\leqslant 5} < 145$	Heat preservation in winter > heat insulation in summer
Hot-summer and cold-winter zone	$0℃ < t_{min \cdot m} \leqslant 10℃$ $25℃ < t_{max \cdot m} \leqslant 30℃$	$0 \leqslant d_{\leqslant 5} < 90$ $40 \leqslant d_{\geqslant 25} < 110$	Heat insulation in summer > heat preservation in winter
Hot-summer and warm-winter zone	$10℃ < t_{min \cdot m}$ $25℃ < t_{max \cdot m} \leqslant 29℃$	$100 \leqslant d_{\geqslant 25} < 200$	The thermal insulation in summer must be considered
Moderate zone	$0℃ < t_{min \cdot m} \leqslant 13℃$ $18℃ < t_{max \cdot m} \leqslant 25℃$	$0 \leqslant d_{\leqslant 5} < 90$	The heat preservation should be considered in partial districts

Standards

- **GB 50189-2005——"Design standard for energy efficiency of public buildings"**(Has been replaced by 2015 version)
- **JGJ 26-2010——"Design standard for energy efficiency of residential buildings in severe cold and cold zones"** (Has been replaced by 2018 version)
- **JGJ 134-2010——"Design standard for energy efficiency of residential buildings in hot summer and cold winter zones"** (Under revision in 2020)
- **JGJ 75-2012——"Design standard for energy efficiency of residential buildings in hot summer and warm winter zones"**

✓A further 30% reduction based on JGJ 26-1995, and achieve 65% building energy saving rate;

✓The specific energy efficiency design standard for residential buildings in different climate zones were published;

✓Building energy efficiency design standards are gradually covering the whole country;

Standards

- **GB/T 51359-2019——"Technical standard for nearly zero energy buildings"**

✓ Proposing the definition and corresponding evaluation indexes of Ultra-low energy building, Nearly zero energy building and zero energy building;

➢ **Ultra-low energy buildings:** Without the help of renewable energy, 50% building energy saving rate should be achieved compared to 2010~2015's relevant standards;

Residential buildings

		Severe cold zones	Cold zones	Hot summer and cold winter zones	Moderate zones	Hot summer and warm winter zones
Building energy consumption		$\leqslant$65(kWh/(m²·a)) $\leqslant$8.0(kgce/(m²·a))				
Building performance index	Annual heating demand (kWh/(m²·a))	$\leqslant$30	$\leqslant$20	$\leqslant$10		$\leqslant$5
	Annual cooling demand (kWh/(m²·a))	$\leqslant 3.5 + 2.0 \times WDH_{20} + 2.2 \times DDH_{28}$				
	Air tightness of building envelope (air change rate N_{50})	$\leqslant$0.6		$\leqslant$1.0		

✓ Meet the requirement of limiting value;

Public buildings

		Severe cold zones	Cold zones	Hot summer and cold winter zones	Moderate zones	Hot summer and warm winter zones
Building energy saving rate		$\geqslant$50%				
Building performance index	Building energy efficiency improvement rate	$\geqslant$25%		$\geqslant$20%		
	Air tightness of building envelope (air change rate N_{50})	$\leqslant$1.0		—		

✓ Meet the requirement of energy saving ratio;

Standards

➢ **Nearly zero energy buildings:** With the help of renewable energy contribution, realize 60%~75% reduction of building energy consumption compared to 2010~2015's relevant standards;

Residential buildings

Building energy consumption		$\leqslant$55(kWh/(m²·a)) $\leqslant$6.8(kgce/(m²·a))				
Building performance index	Annual heating demand (kWh/(m²·a))	Severe cold zones	Cold zones	Hot summer and cold winter zones	Moderate zones	Hot summer and warm winter zones
		$\leqslant$18	$\leqslant$15	$\leqslant$8		$\leqslant$5
	Annual cooling demand (kWh/(m²·a))	$\leqslant 3+1.5\times WDH_{20}+2.0\times DDH_{28}$				
	Air tightness of building envelope (air change rate N_{50})	$\leqslant$0.6		$\leqslant$1.0		
Utilization ratio of renewable energy		$\geqslant$10%				

Public buildings

Building energy saving rate		$\geqslant$60%				
Building performance index	Building energy efficiency improvement rate	Severe cold zones	Cold zones	Hot summer and cold winter zones	Moderate zones	Hot summer and warm winter zones
		$\geqslant$30%		$\geqslant$20%		
	Air tightness of building envelope (air change rate N_{50})	$\leqslant$1.0		—		
Utilization ratio of renewable energy		$\geqslant$10%				

First nearly zero energy building in China, 2014

——CABR's office building

Standards

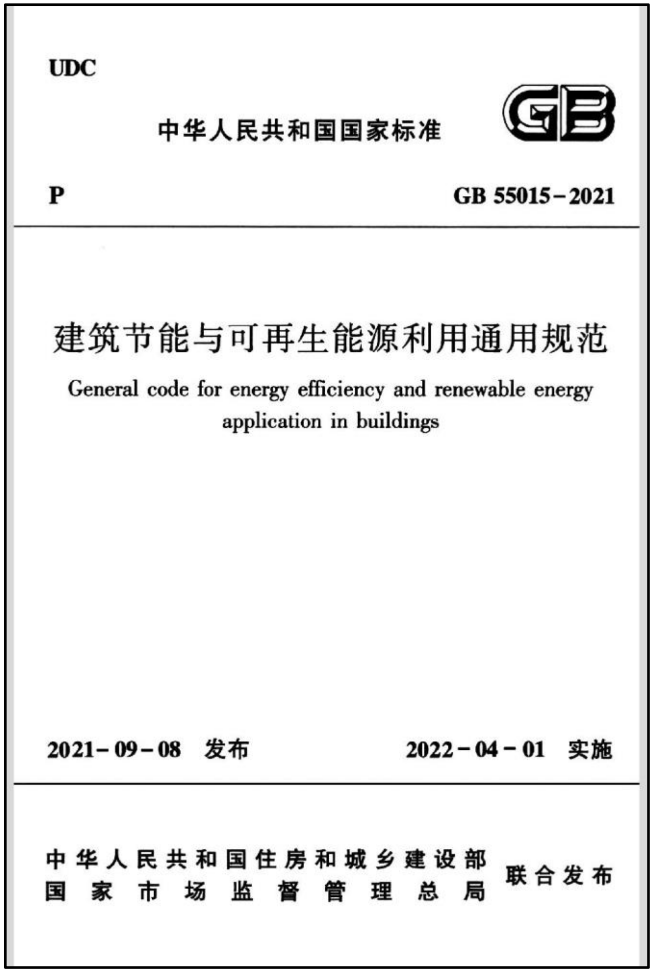
- **GB 55015-2021——"General code for energy efficiency and renewable energy application in buildings"**

✓ Full-text mandatory standard;

✓ Solar energy system should be installed in new buildings;

✓ For residential buildings, 75% building energy saving rate should be achieve in severe cold and cold zones, and 65% building energy saving rate in other climate zones;

✓ For public buildings, 72% building energy saving rate should be achieve;



UDC

中华人民共和国国家标准 GB

P GB 55015－2021

建筑节能与可再生能源利用通用规范

General code for energy efficiency and renewable energy application in buildings

2021－09－08 发布 2022－04－01 实施

中华人民共和国住房和城乡建设部
国家市场监督管理总局 联合发布

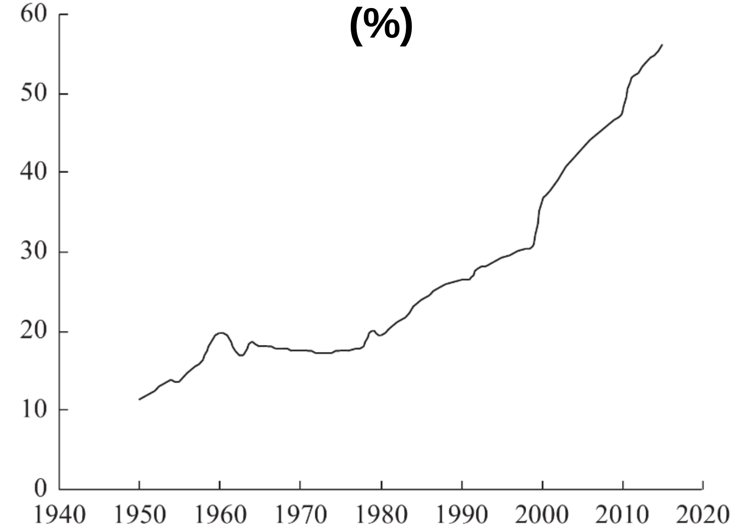
Technical standard for zero carbon buildings

- **Challenge in building carbon reduction**

✓ China's urbanization level is gradually improving, and there will be about 2,000,000,000.00 m^2 of new building area per year;

✓ Existing technology is difficult to support buildings to achieve the "30·60" target timely;

Urbanization rate in China (%)



- **Technical standard for zero carbon buildings**

✓ In 2021, the national standard of zero carbon buildings start establishment;

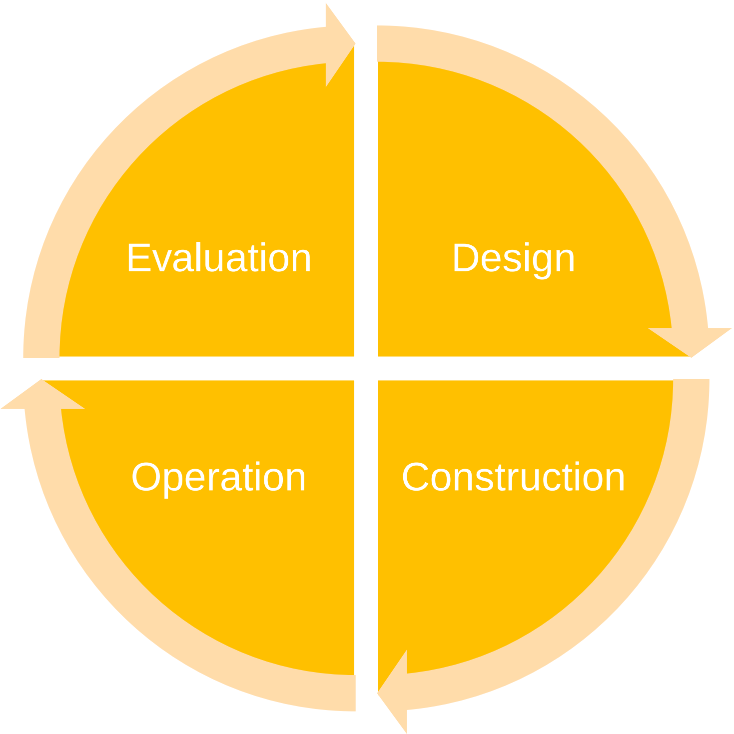
✓ In Jul, 2023, the first draft of the standard is open to the whole society for opinions;

Technical standard for zero carbon buildings

The standard covers all the life cycle of buildings

- **Main content**

1. General rule
2. Nomenclature
3. Technical indicators
4. Building carbon reduction design
5. District carbon reduction design
6. Low carbon construction
7. Low carbon operation
8. Test and evaluation
9. Carbon offset

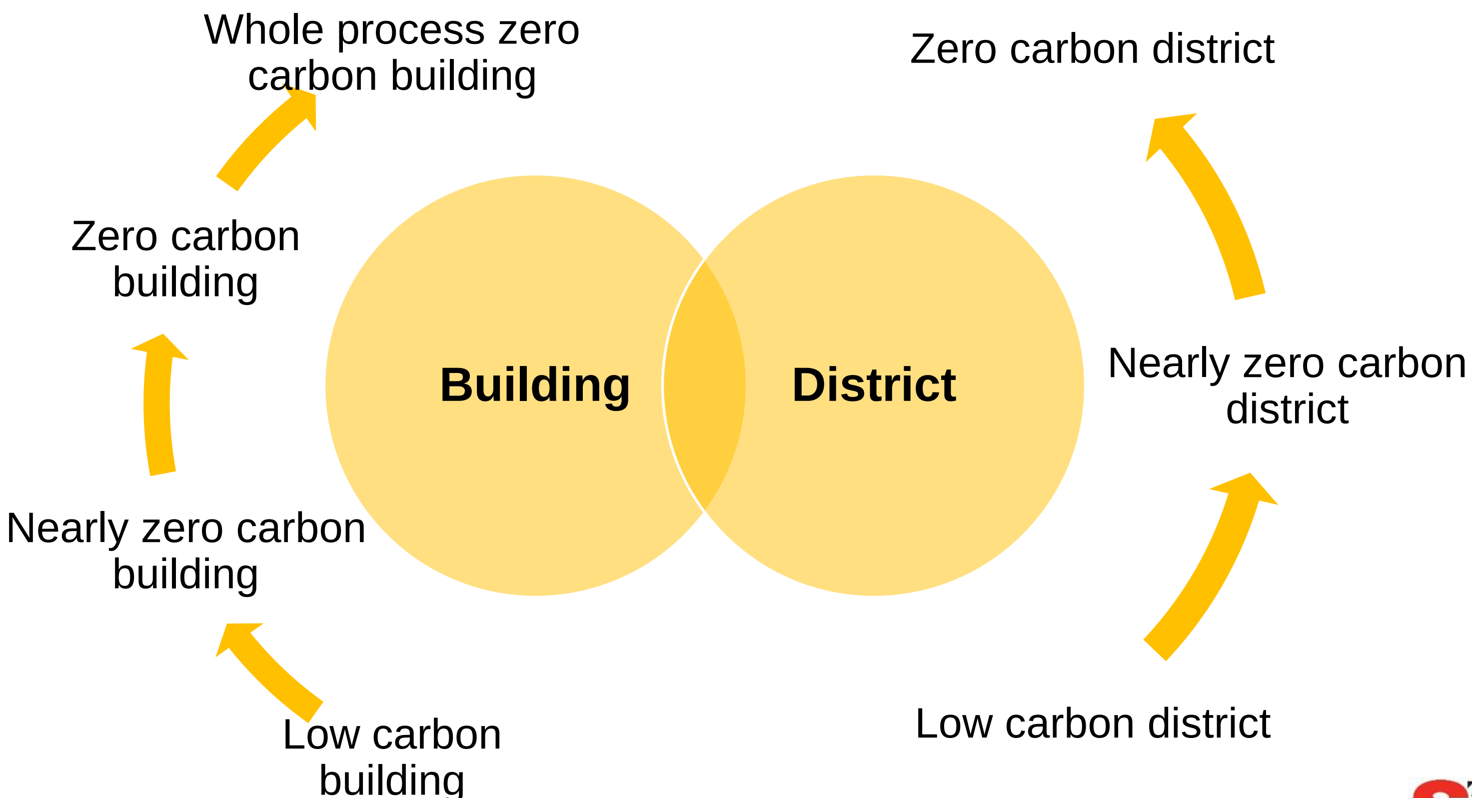


Building life cycle

Technical standard for zero carbon buildings

- **Evaluation objects and levels**

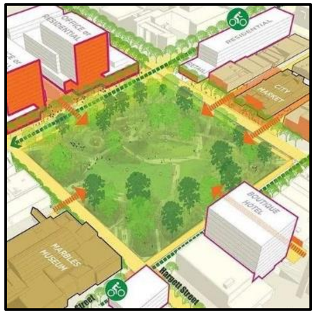
✓ The standard applies to single building and building district;



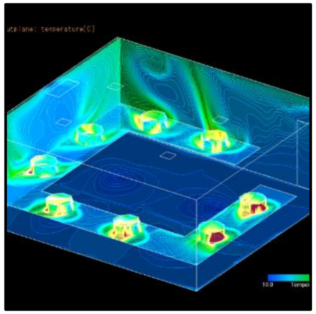
Technical standard for zero carbon buildings

- **Low carbon and nearly zero carbon building**

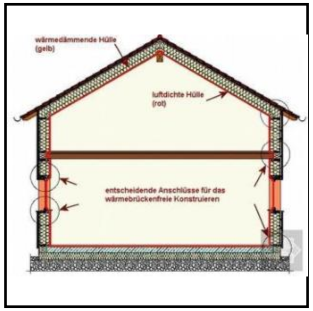
✓ The following conditions should be considered during the building design;



Local climate characteristics & site conditions;



Indoor environment parameters;



Passive design;

Equipment & systems;

Renewable energy & storage;

- **Zero carbon building**

✓ On the basis of achieving nearly zero carbon buildings, the annual carbon emission is no more than 0 through the carbon offset methods (carbon offset ratio ≤ 30%), such as carbon emission right trade, green electricity trading and etc.

- **Whole process zero carbon building**

✓ The embodied carbon emission should less than 350 kgCO_2/m^2;

Technical standard for zero carbon buildings

- **Calculation method for buildings**

✓ Carbon emission intensity;

$$C=(E_h \times c_i+E_c \times c_i+E_l \times c_i+E_w \times c_i+E_e \times c_i+E_p \times c_i+E_f \times c_i-E_r \times c_i)/A$$

C: carbon emission intensity, $kgCO_2/m^2$;

E_h: heating energy consumption, kWh;

E_c: cooling energy consumption, kWh;

E_l: lighting energy consumption, kWh;

E_w: domestic hot water energy consumption, kWh;

E_e: elevator energy consumption, kWh;

E_p: equipment energy consumption, kWh;

E_f: cooking energy consumption, kWh;

E_r: renewable energy generation, kWh;

c_i: carbon emission factor from GB/T 51366 "Standard for building carbon emission calculation";

A: building area, m^2.

✓ Carbon reducing ratio;

$$H_p=|C_R-C_D|/C_R \times 100\%$$

η_p: carbon reducing ratio, %;

C_R: carbon emission intensity of reference building, $kgCO_2/m^2$, reference GB 55015-2021;

C_D: carbon emission intensity of design building, $kgCO_2/m^2$.

Technical standard for zero carbon buildings

- **Index for residential buildings**

✓ Low carbon buildings: set different carbon emission intensity limiting value according to different climate zones;

✓ Nearly zero carbon buildings: the radiation levels was taken into account in determining the limiting value;

limiting value for low carbon residential buildings ($kgCO_2/m^2 \cdot a$)

	Severe cold zones	Cold zones	Hot summer and cold winter zones	Hot summer and warm winter zones	Moderate zones
Carbon emission intensity	23	21	21	23	18

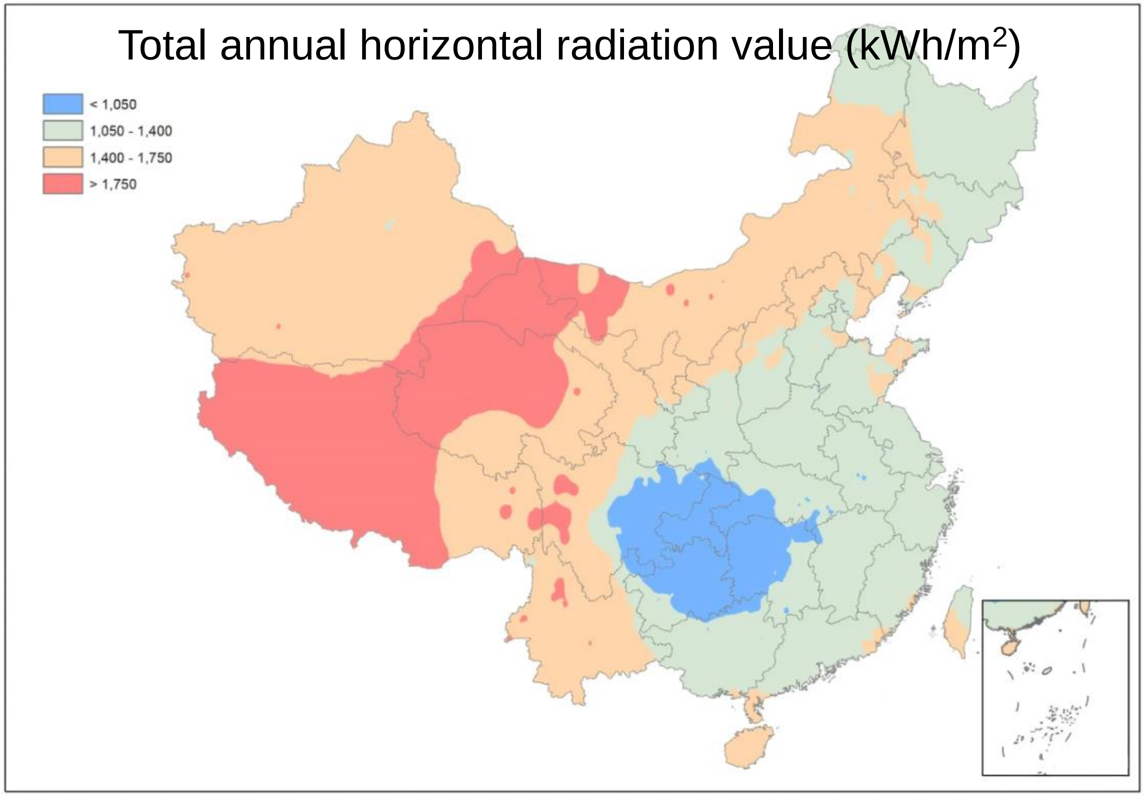
Limiting value for nearly zero carbon residential buildings ($kgCO_2/m^2 \cdot a$)

	Climate zones / Radiation levels	Severe cold zones	Cold zones	Hot summer and cold winter zones	Hot summer and warm winter zones	Moderate zones
Carbon emission intensity	Ⅰ	14	13	/	/	/
	Ⅱ	15	14	/	16	12
	Ⅲ	16	16	16	17	13
	Ⅳ	/	/	17	/	14

Technical standard for zero carbon buildings

- **Radiation levels in China**

✓ GB/T 31155-2014——"Classification of solar energy resources——Global radiation"



Levels	Values ($kWh/m^2 \cdot a$)
I	G≥1750
II	1400≤G＜1750
III	1050≤G＜1400
IV	G＜1050
G: total annual radiation (30 years average)	

Technical standard for zero carbon buildings

- **Index for public buildings**

✓ The situation of building functions, climate zones and solar radiation were taken into account in determining the limiting value of carbon emission;

✓ There are 2 indexes for public buildings, and only one of them need to be achieved;

Index for low carbon public buildings

Climate zones	Carbon reducing ratio	Carbon emission intensity ($kgCO_2/m^2$)						
		Small office	Large office	Small hotel	Large hotel	Shopping mall	Medical treatment	school
Severe cold zones	≥40%	23	25	30	35	65	55	15
Cold zones	≥35%	21	25	30	40	68	55	16
Hot summer and cold winter zones	≥30%	21	28	33	43	75	60	20
Hot summer and warm winter zones		23	30	36	45	85	65	25
Moderate zones		18	22	28	30	63	45	13

Technical standard for zero carbon buildings

- **Index for public buildings**

Index for nearly zero carbon public buildings

Climate zones	Carbon reducing ratio	Radiation level	Carbon emission intensity ($kgCO_2/m^2 \cdot a$)						
			Small office	Large office	Small hotel	Large hotel	Shopping mall	Medical treatment	School
Severe cold zones	≥55%	I	16	19	20	24	49	40.5	10
		II	17	20	22	25	51	42.5	11
		III	18	21	24	26.5	53.5	44.5	12
Cold zones	≥50%	I	14	18	20	27	51.5	42.5	11
		II	15	19	22	28.5	54	43.5	12
		III	16	20	24	30	56	45	13
Hot summer and cold winter zones	≥45%	III	16	23	22	30	61	47	16
		IV	17	24	24	31	63	49	17
Hot summer and warm winter zones		II	16	24	27	33	69	50	20
		III	17	25	29	35	70	52	21
Moderate zones		II	12	18	18	22	49 .5	35	9
		III	13	18	19	23	52	37	10
		IV	14	18	21	25	54	38	11

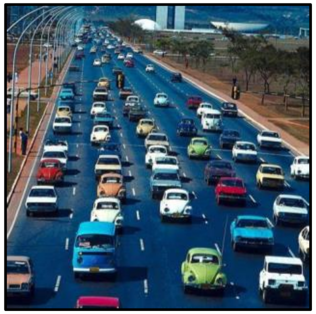
Technical standard for zero carbon buildings

- **Low carbon and nearly zero carbon district**

✓ A geographical area with clear physical boundaries and mainly functions, such as residence, office, medical treatment, business and teaching;

✓ The following items should be considered to calculate the carbon emission of district;


buildings


Traffic


Municipal


Renewable energy


Carbon sink

- **Zero carbon district**

✓ The annual carbon emission is no more than 0, through the carbon offset methods (carbon offset ratio ≤ 30%), such as carbon emission right trade, green electricity trading and etc.;

Technical standard for zero carbon buildings

- **Calculation method for district**

✓ District carbon emissions per capita:

$$C_p=C_d/P$$

C_p: district carbon emission per capita, $tCO_2/p \cdot a$;
C_d: district carbon emission, tCO_2/a;
P: total number of people in district, p;

✓ District carbon emission:

$$C_d=C_{d,b}+C_{d,t}+C_{d,m}+C_{d,o}-C_{d,r}-C_{d,s}-C_{d,e}$$

$C_{d,b}$: building carbon emission, tCO_2/a;
$C_{d,t}$: traffic carbon emission, tCO_2/a;
$C_{d,m}$: municipal carbon emission, tCO_2/a;
$C_{d,o}$: others carbon emission, tCO_2/a;
$C_{d,r}$: carbon reduction of renewable energy generation, tCO_2/a;
$C_{d,s}$: carbon reduction of carbon sink, tCO_2/a;
$C_{d,e}$: carbon emission of energy transported outside the district, tCO_2/a.

✓ District carbon reduction ratio:

$$R_{CC}=|C_{rd}-C_{dd}|/C_{rd}\times 100\%$$

R_{CC}: district carbon reduction ratio, %;
C_{rd}: reference district carbon emission, tCO_2/a;
C_{dd}: design district carbon emission, tCO_2/a;

Technical standard for zero carbon buildings

- **Calculation method for district**

✓ Building carbon emission:

$$C_{d,b}=\Sigma_i(C_{E,i}\times A_{b,i})/1000$$

$C_{E,i}$: carbon emission intensity of the i^{th} building, $kgCO_2/m^2\cdot a$;
$A_{b,i}$: building area of the i^{th} building, m^2;

✓ Municipal carbon emission:

$$C_{d,m}=C_{d,m1}+C_{d,m2}+C_{d,m3}$$

$C_{d,m1}$: carbon emission of waste disposal, tCO_2/a;
$C_{d,m2}$: carbon emission of district water supply system, tCO_2/a;
$C_{d,m3}$: carbon emission of municipal lighting, tCO_2/a;

$$C_{d,m1}=\Sigma_i(Wa_i\times P_i)\times EF_{wa}\times 365/1000$$

Wa_i: waste disposal capacity per capita of the i^{th} building, kg/(p·a);
P_i: total number of people in the i^{th} building, p;
EF_{wa}: carbon emission factor of waste disposal, $kgCO_2/kg$;

$$C_{d,m2}=\Sigma_i(W_i\times P_i\times EF_w\times 365)/1000$$

W_i: daily water consumption of the i^{th} building, $m^3/(p\cdot d)$;
P_i: total number of people in the i^{th} building, p;
EF_w: municipal water supply and sewage disposal carbon emission factor, $kgCO_2/m^3$;

$$C_{d,m3}=A_r\times ML\times t\times EF_1/1000000$$

A_r: area of municipal road, m^2;
ML: power density of municipal lighting, W/m^2;
t: lighting annual service hours, hr;
EF_1: carbon emission factor of electricity, $kgCO_2/kWh$;

Technical standard for zero carbon buildings

- **Calculation method for district**

✓ Traffic carbon emission:

$$C_{d,t}=\Sigma_i\Sigma_j(L_{i,j}\times D_{i,j})\times EF_i/1000$$

$L_{i,j}$: the annually total distance of the j^{th} vehicle using the i^{th} energy source, km/a;
$D_{i,j}$: energy consumption per unit distance, L/km (kWh/km for e-mobility);
EF_i: carbon emission factor of the i^{th} fuel, $kgCO_2/L$ ($kgCO_2/kWh$ for e-mobility);

✓ Other fuel carbon emission:

$$C_{d,o}=\Sigma_i(O_i\times EF_i)$$

O_i: energy consumption of the i^{th} fuel, units/a;
EF_i: carbon emission of the i^{th} fuel, $kgCO_2$/units;

✓ Carbon reduction of renewable energy generation:

$$C_{d,r}=\Sigma_i(E_i\times EF_i)/1000$$

E_i: annually generation of the i^{th} renewable energy, kWh/a;
EF_i: carbon emission factor of the i^{th} renewable energy, $kgCO_2/kWh$;

✓ Carbon reduction of carbon sink:

$$C_{d,s}=A_s\times EF_s$$

A_s: total area of green, m^2;
EF_s: carbon sink capacity of green, $tCO_2/m^2\cdot a$;

Technical standard for zero carbon buildings

- **Index for district**

Index for low carbon district

Climate zones	Carbon reduction ratio	Radiation levels	Carbon emission per capita ($kgCO_2/p·a$)					
			Resident	office	Hospital	Shopping mall	School	
							Primary and middle school	collage
Severe cold zones	≥30%	I	1040	490	1920	1020	390	980
		II	1090	470	1900	1010	410	1020
		III	1140	450	1880	1000	430	1060
Cold zones		I	940	470	1920	1010	390	970
		II	990	450	1900	1000	400	1000
		III	1030	430	1880	990	420	1040
Hot summer and cold winter zones		III	1070	470	1870	1010	410	1020
		IV	1120	450	1850	1000	430	1060
Hot summer and warm winter zones		II	1100	460	1860	1110	410	1010
		III	1140	430	1840	1100	420	1040
Moderate zones		II	820	460	1620	920	380	950
		III	860	440	1610	910	390	980
		IV	910	420	1600	900	410	1010

Technical standard for zero carbon buildings

- Index for district

Index for nearly zero carbon district

Climate zones	Carbon reduction ratio	Radiation levels	Carbon emission per capita ($kgCO_2/p \cdot a$)					
			Resident	Office	Hospital	Shopping mall	School	
							Primary and middle school	collage
Severe cold zones	≥60%	Ⅰ	510	280	600	580	230	560
		Ⅱ	610	270	600	580	240	580
		Ⅲ	700	260	600	570	250	610
Cold zones		Ⅰ	470	270	600	580	230	560
		Ⅱ	570	260	600	570	230	570
		Ⅲ	690	250	600	570	240	590
Hot summer and cold winter zones		Ⅲ	690	270	600	580	240	590
		Ⅳ	790	260	600	570	250	610
Hot summer and warm winter zones		Ⅱ	650	260	600	600	230	580
		Ⅲ	740	250	600	600	240	600
Moderate zones		Ⅱ	430	260	600	530	220	550
		Ⅲ	520	250	600	520	230	560
		Ⅳ	620	240	600	510	230	580

Conclusion

- **Throughout the development trend of China's construction industry in recent years, the development of zero carbon buildings:**

✓ Be an inevitable requirement to promote the comprehensive utilization of resources, construct a conservation-oriented society, and develop circular economy;

✓ Be a key link to save energy and ensure the national energy security;

✓ Lead the direction of development for future buildings in China.

Thank you for listening!

CAI Wenbo, CABR, 10th Oct. 2023, Graz

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