BUILDINGS ENERGY EFFICIENCY CONSORTIUM

U.S. - CHINA CLEAN ENERGY RESEARCH CENTER (CERC-BEE)

Commercial building energy efficiency standard & performance evaluation

U.S. research Leads: Mark Levine, Wei Feng

U.S. and China Industry Partner(s):

U.S. side: Lutron, Dow, Carrier, Trane, Owens-Corning

China side: CABR

YEAR 4 JOINT ANNUAL MEETING

Berkeley California

Presented By Wei Feng

Lawrence Berkeley National Laboratory
Berkeley, CA

Aug 2014

Project introduction

- Project name: “Analysis of commercial building energy efficiency standards”
- Objectives: Understand the commercial building energy standards performance and cost-effectiveness
- Start time: Apr 2014.
- Project period: 2014~2015
- Chinese research counterpart: CABR
- Industrial partners: Lutron, Dow, Carrier, Trane, Owens-Corning, SIEMENS etc.

Tasks (2014, 2015)

- A Chinese prototypical office reference buildings based on available Chinese buildings data augmented by surveys of characteristics of office buildings (2014, finished)
- Energy savings of China's office building meeting the proposed new energy standards, compared with 1980s baseline and the previous 2005 energy standards (2014, finished)
- Cost effectiveness analysis of the new commercial building energy standards (Dec. 2014)
- Analysis of advanced office building energy standards – cost, benefit, energy savings impact – for the next set of standards to be promulgated after 2015 (2015)
- Prototypes for other commercial buildings: government office building, hotel, shopping center in collaboration with CABR (2015)
- Analysis of advanced building energy standards for new prototypes (government building, hotel, shopping mall) – cost, benefit, energy savings impact – for the next set of standards to be promulgated after 2015 (2015)

Impacts

- Existing 2005 standard estimated savings (China):
  - Using 1980's building energy consumption as baseline
  - The existing 2005 version saves 50% heating, and 40% cooling reduction
  - 249 mtce energy savings from 2010 to 2030 (~12.5 mtce/year)
  - 1.1 billion tons CO2 to from 2010 to 2030 (~55 million tons/year)

-- Cited from WRI

- The new 2014 standard savings (China):
  - Using 2005 building energy consumption as baseline
  - Annual energy savings: 3.75 mtce,
  - Annual CO2 abatement: 16.5 M tons

- Codes saving in the U.S.:
  - Annual CO2 abatement: 36 M tons (residential + commercial)

-- Cited from DOE

Project status

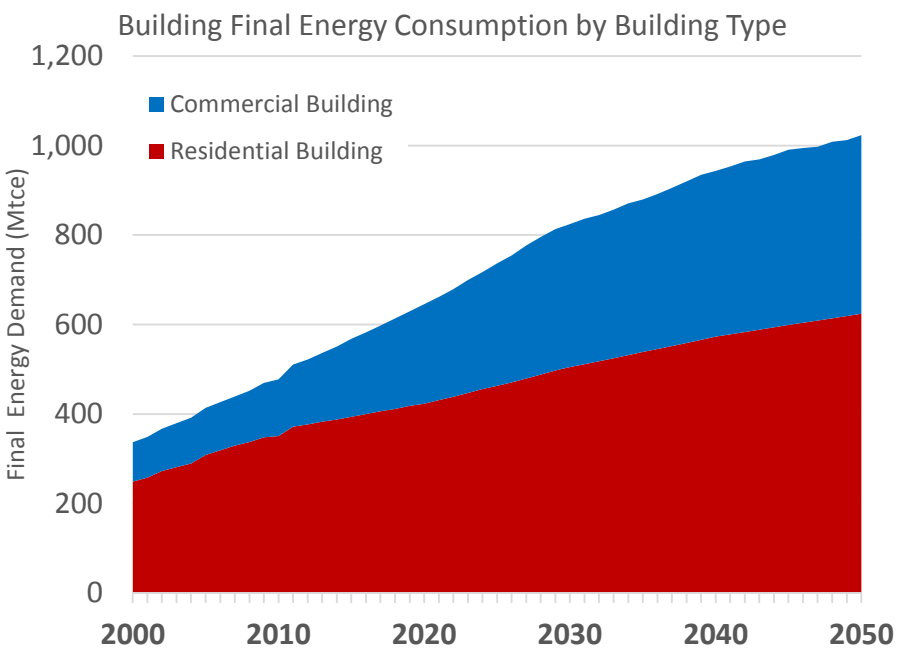
- Outcomes:
  - Influence China to adopt more stringent building energy standard
  - Understand the standard performance and future trend
  - ACEEE paper, working on a journal paper
- Benefit to the U.S.:
  - Promote the penetration of U.S. high performance technologies in Chinese market
  - Bring successful experience of Chinese commercial building standard to ASHRAE 90.1
- Issues:
  - Lack of transparency of building data in Chinese market
- Funding:
  - 2014, 70K allocated
- Demonstration building:
  - The new standard serves as an energy baseline for all demonstration buildings' energy performance analysis

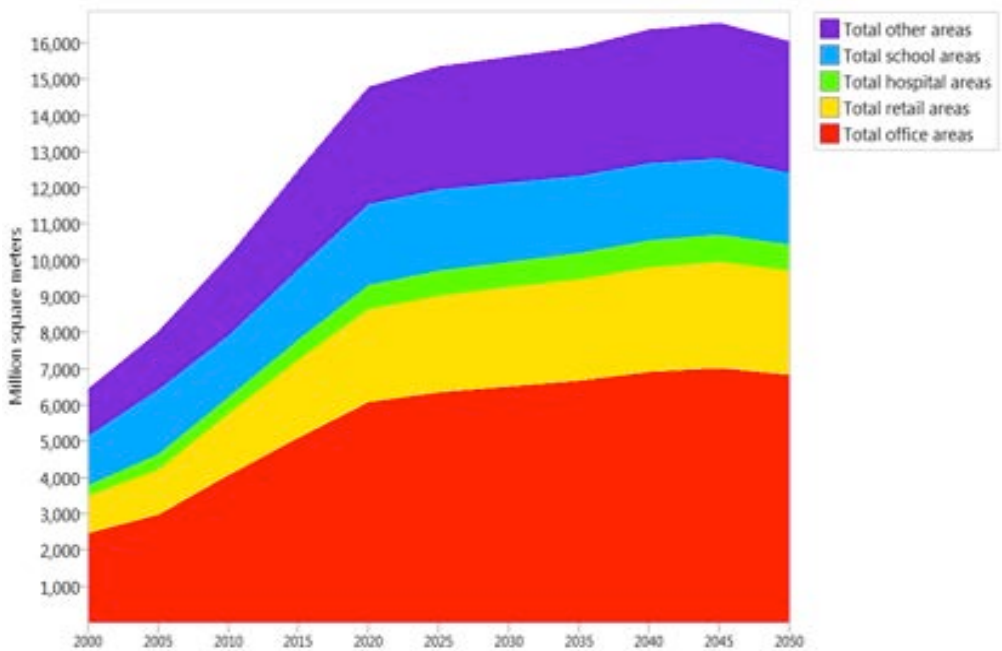
Background

- From 1996 to 2008, total floor space of commercial buildings in China increased from 2.8 billion m^2 to 7.1 billion m^2.
- Commercial building floor space increases approximately 0.5 billion m^2/year
- Commercial building energy efficiency standard in China: GB50189
- First issued in 1993 with initial focus to regulate energy consumption in hotels
- A comprehensive update in 2005 – 50% more efficient than the 1980 baseline
- A new upgrade in 2014 – expect 65% more efficient than the 1980 baseline, or 30% more efficient than the 2005 standard. No upgrade in the past 9 years!

Background

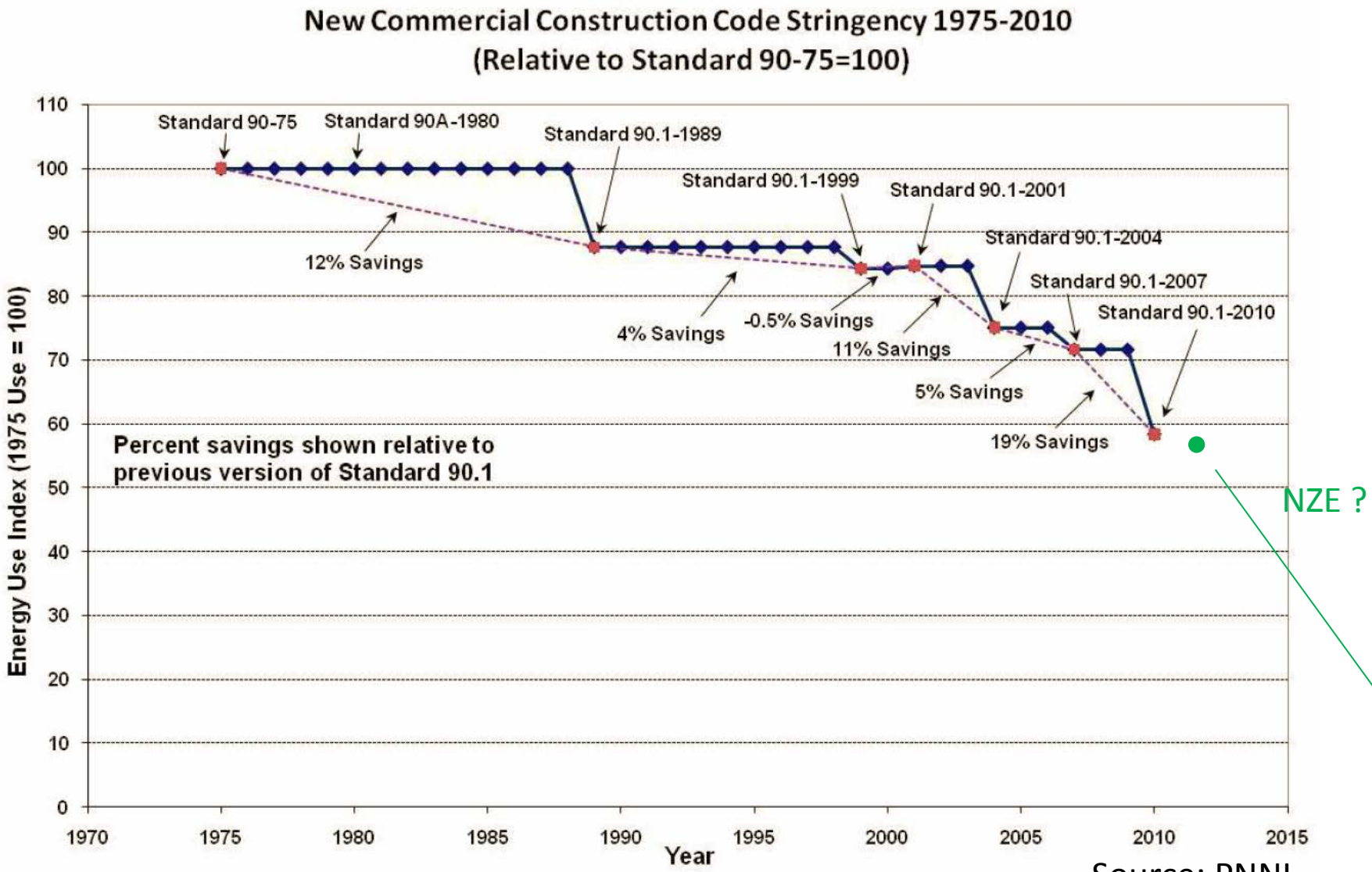
- Commercial buildings consume ~50% primary energy in U.S. building sector, and 1/4 primary energy in China. But it is projected that the commercial building energy consumption in China will continue increase in the future.





Commercial building floor space projection in China

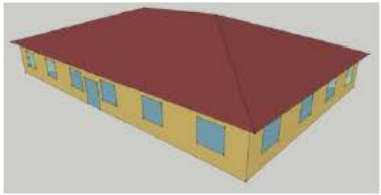
ASHRAE 90.1 improvement



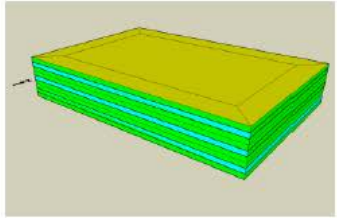
Source: PNNL

Reference buildings – evaluate code compliant savings
参考建筑，用于评价公共建筑节能标准性能

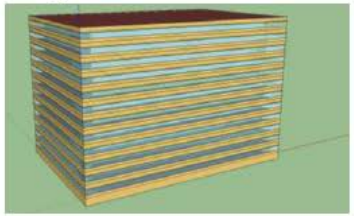
Small Office



Medium Office



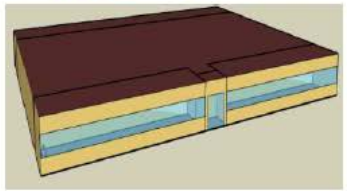
Large Office



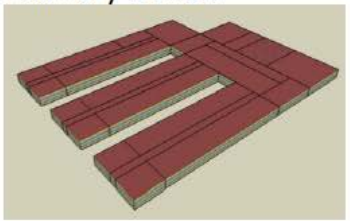
Warehouse

Strip Mall Retail

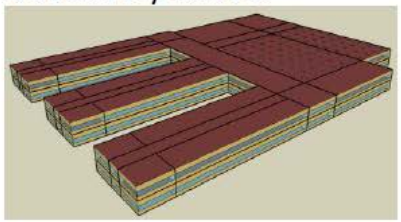
Standalone Retail



Primary School

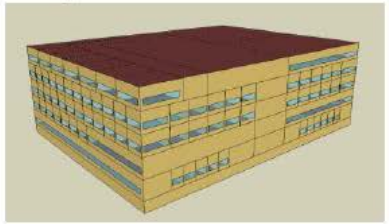


Secondary School



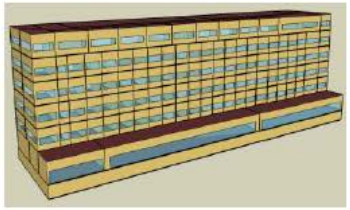
Outpatient Healthcare

Hospital

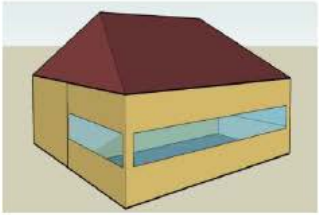


Small Hotel

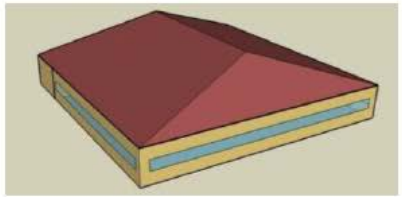
Large Hotel



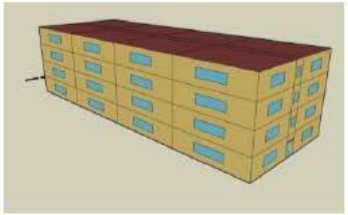
Quick-service Restaurant



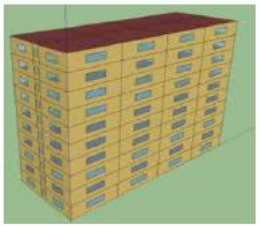
Full-service Restaurant



Mid-rise Apartment

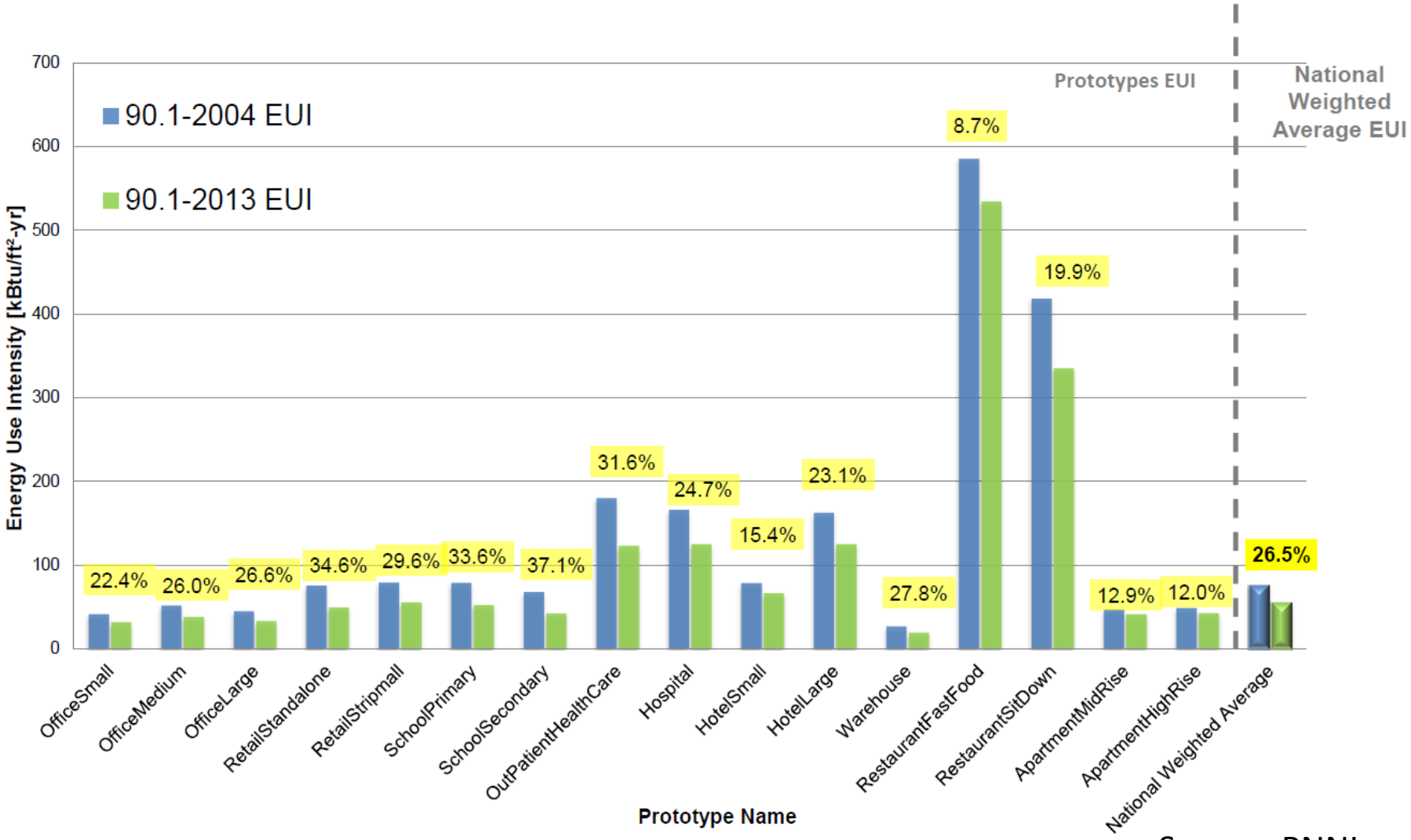


High-rise Apartment



Source: PNNL

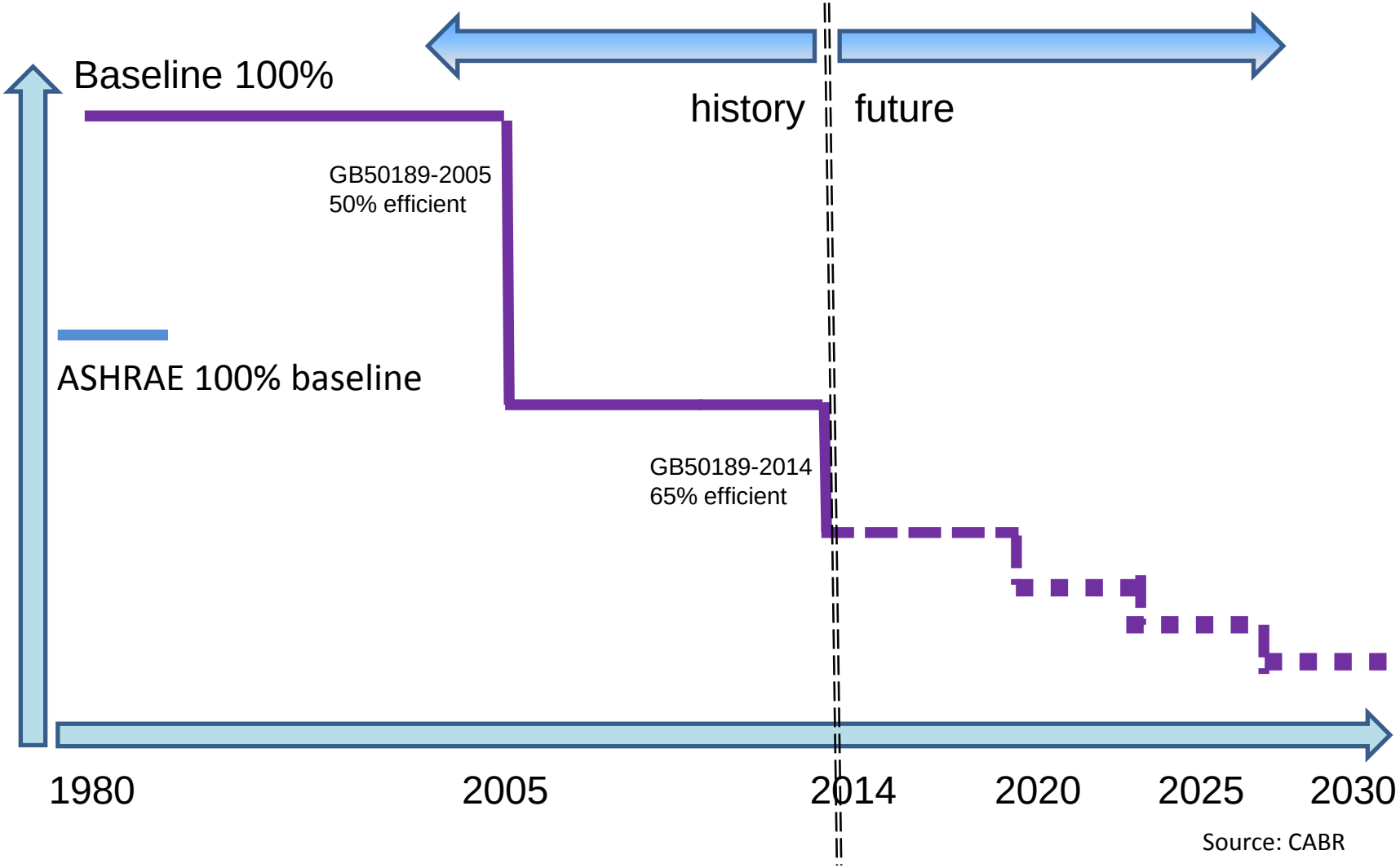
ASHRAE 90.1 Savings analysis 节能量分析



Source: PNNL

Chinese commercial building standard improvement roadmap

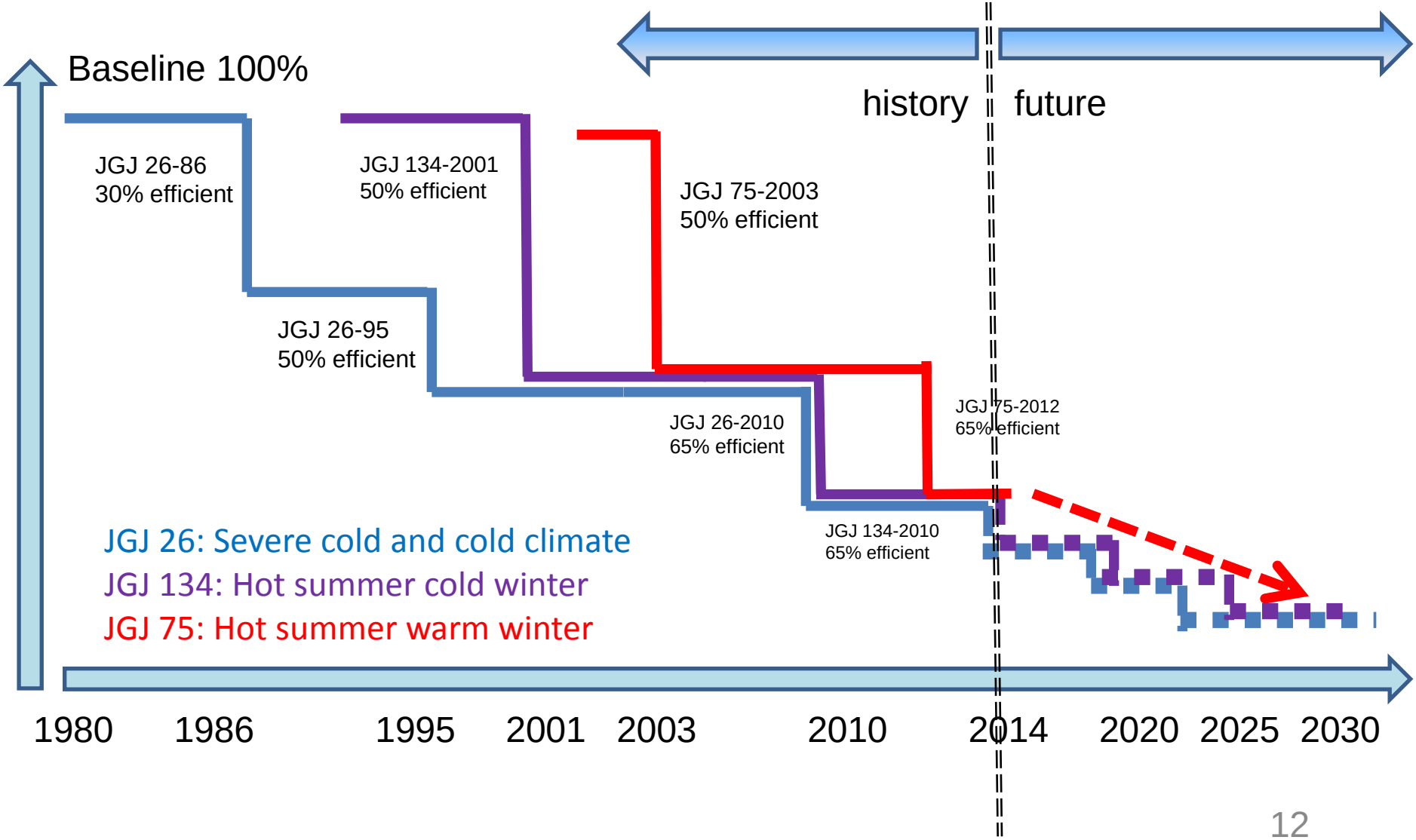
Roadmap and Future R&D Work 路线图-公共建筑



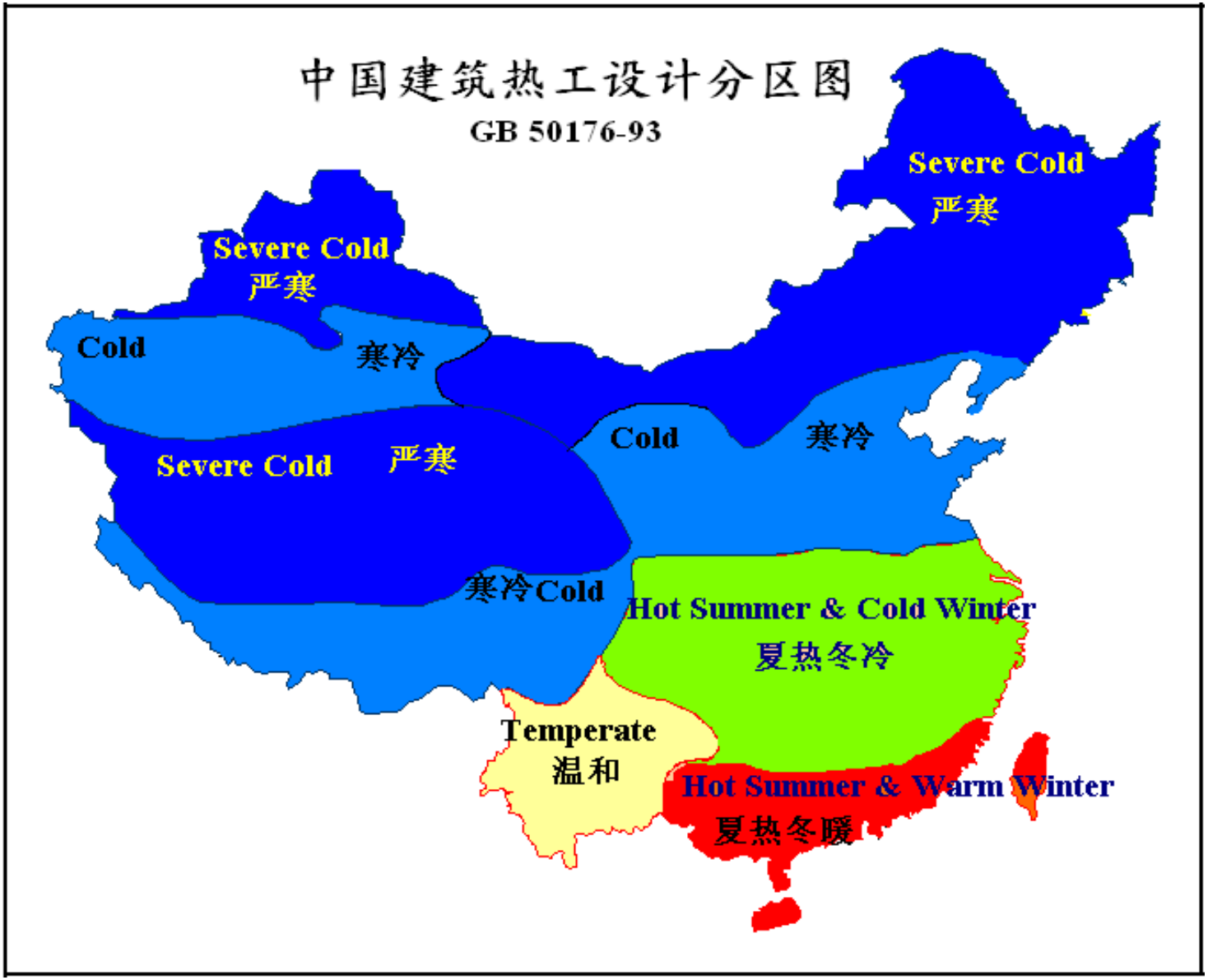
Source: CABR

Chinese residential building standard improvement roadmap

Roadmap and Future R&D Work 路线图-居住建筑



Climate zones in China



Climate zones comparison between ASHRAE and Chinese standards

US climate zone	US feature	CDD/ HDD	China feature	China climate zone	China typical city
1	Very Hot-Dry (1A) Very Hot-Humid (1B)	5000 < CDD10	N/A	N/A	N/A
2	Hot-Dry (1A) Hot-Humid (1B)	3500 < CDD10 ≤ 5000	coldest >10℃, hottest 25~29℃, average temp ≥25℃ days≥100~200	Hot summer and warm winter area	Guangzhou
3A, 3B	Warm-Humid (3A) Warm-Dry (3B)	2500＜CDD10 ≤ 3500	coldest 0~10℃, hottest 25~30℃, average temp ≥ 25℃ days ≥ 40~110	Hot summer and cold winter area	Shanghai
3C	Warm- Marine	CDD10 ≤ 2500 HDD18 ≤ 2000			
4A, 4B	Mixed-Humid (4A) Mixed-Dry (4B)	CDD10 ≤ 2500 2000＜HDD18 ≤ 3000	2000＜HDD18 ≤ 3800, CDD26＞ 90	cold B	Beijing (HDD18=2699,CDD26=94)
4C	Mixed-Marine	2000＜HDD18 ≤ 3000	2000＜HDD18 ≤ 3800, CDD26 ≤ 90	cold A	
5A, 5B, 5C	Cold-Humid (5A) Cold-Dry (5B) Cold-Marine (5C)	3000＜HDD18 ≤ 4000	3800＜HDD18 ≤ 5000	Extremely cold C	Harbin (HDD18=5032,CDD26=14)
6A, 6B	Cold-Humid (6A) Cold-Dry (6B)	4000＜HDD18 ≤ 5000			
7	Very Cold	5000＜HDD18 ≤ 7000	5000＜HDD18 ≤ 6000	Extremely cold B	
8	Subarctic	7000＜HDD18	6000＜HDD18	Extremely cold A	N/A

Envelope measures comparison -- fenestration

	ASHRAE90.1-2013			GB50189-2005						GB50189-2014					
	Framing Type	U	SHGC max	S≤0.3			0.3＜S≤0.4			S≤0.3			0.3＜S≤0.4		
				WWR	U	SHGC (E, S, W/N)	WWR	U	SHGC(E, S, W/N)	WWR	U	SHGC (E, S, W/N)	WWR	U	SHGC(E, S, W/N)
Vertical Fenestration, 0%~40% WWR for ASHRAE 90.1	Nonmetal framing	1.82	0.4	≤0.2	3.5	-	≤0.2	3	-	≤0.2	3	-	≤0.2	2.8	-
	Metal framing, fixed	2.38		0.2-0.3	3	-	0.2-0.3	2.5	-	0.2-0.3	2.7	0.52/-	0.2-0.3	2.5	0.52/-
	Metal framing, operable	2.84		0.3-0.4	2.7	0.588/-	0.3-0.4	2.3	≤0.588/-	0.3-0.4	2.4	0.48/-	0.3-0.4	2.2	0.48/-
	Metal framing, entrance door	4.37		0.4-0.5	2.3	0.50/-	0.5-0.5	2	≤0.50/-	0.4-0.5	2.2	0.43/-	0.4-0.5	2	0.43/-
				0.5-0.7	2	0.42/-	0.5-0.7	1.8	≤0.42/-	0.5-0.6	2	0.40/-	0.5-0.6	1.8	0.40/-
										0.6-0.7	2	0.35/0.60	0.6-0.7	1.8	0.35/0.60
				N/A						0.7-0.8	1.8	0.35/0.52	0.7-0.8	1.6	0.35/0.52
										0.8-1.0	1.5	0.30/0.52	0.8-1.0	1.4	0.30/0.52
skylight, 0%~3% of Roof	2.84		0.4	N/A						N/A					

Envelope measures comparison – exterior wall

U value (unit: W/(K m²)	ASHRAE90.1-2013		GB50189-2005		GB50189-2014	
			S≤0.3	0.3＜S≤0.4	S≤0.3	0.3＜S≤0.4
roof	Insulation Entirely above Deck	0.184	0.55	0.45	0.45	0.4
	Metal Building	0.21				
	Attic and Other	0.119				
wall	Mass	0.513	0.6	0.5	0.5	0.45
	Metal Building	0.286				
	Steel Framed	0.315				
	Wood Framed, Other	0.291				

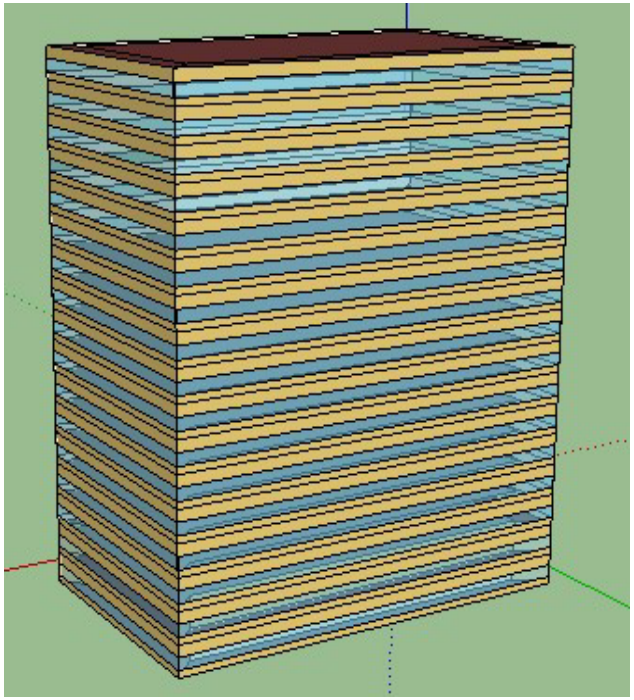
Chiller performance

	ASHRAE90.1-2013			GB50189-2005				GB50189-2014		
	Path A									
	CC (kW)	COP	IPLV	Type	CC (kW)	COP	IPLV	CC (kW)	COP	IPLV
Water cooled	＜264	4.69	5.87	Reciprocating /Scroll	<528	3.8	N/A	≤528	4.1	4.9
	264-528	4.89	6.29							
	528-1055	5.33	6.52		528-1055	4		N/A		
	1055-2110	5.77	6.77		1055-1163					
	1163-2110				>1163	4.2				
	＞2110	6.29	7.04							
	＜264	4.69	5.87	Screw	＜528	4.1	4.47	≤528	4.7	5.45
	264-528	4.89	6.29							
	528-1055	5.33	6.52		528-1055	4.3	4.81	528-1163	5.1	5.85
	1055-1163	5.77	6.77		1055-1163					
	1163-2110				＞1163	4.6	5.13	＞1163	5.5	6.2
	＞2110	6.29	7.04							
	＜528	5.77	6.4	Centrifugal	＜528	4.4	4.49	≤1163	5.2	5.35
	528-1055				528-1055	4.7	4.88	1163-2110	5.5	5.6
	1055-1163	6.29	6.77		1055-1163					
	1163-1407				＞1163	5.1	5.42	＞2110	5.8	6.1
	1407-2110		7.04							
	＞2110									
Air cooled	≤528	2.99	4.05	Reciprocating /Scroll	≤50	2.4	N/A	≤50	2.6	3.1
			4.14		＞50	2.6		＞50	2.8	3.35
	＞528		4.05	Screw	≤50			≤50		3
			4.14		＞50	2.8		＞50	3	3.2

Lighting power density

Building type (unit: W/m^2)	ASHRAE90.1-2013	GB50189-2005	GB50189-2014
Office	8.8	11	9
Hotel/motel	9.4	15	7
Retail	13.6	12	10
School/University	9.4	n/a	9
Hospital	11.3	n/a	10

Evaluate the performance: Chinese reference buildings



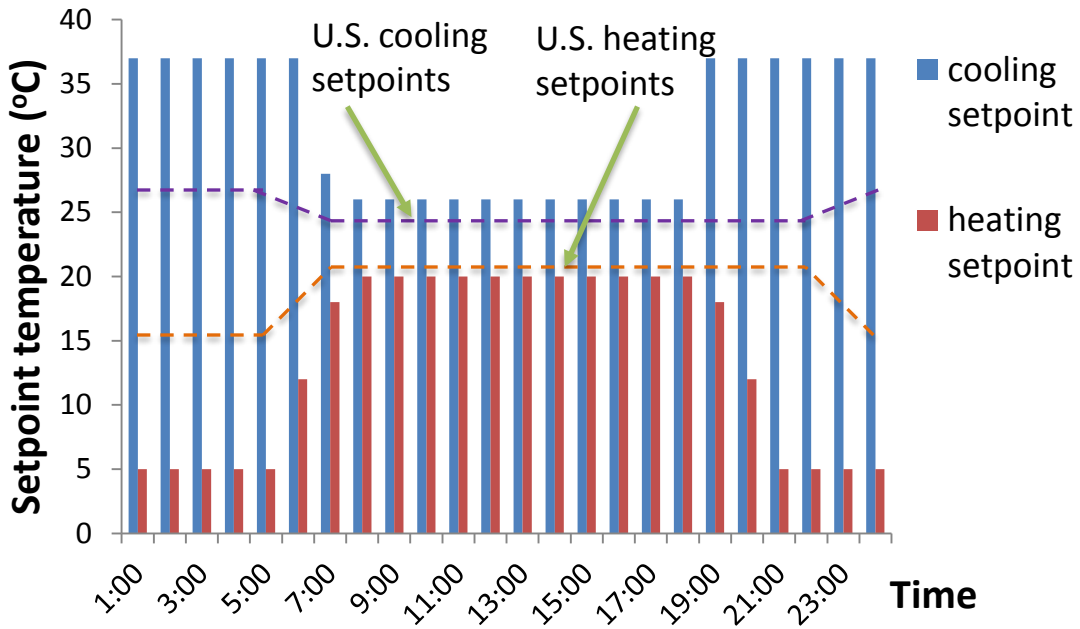
Chinese large office reference building

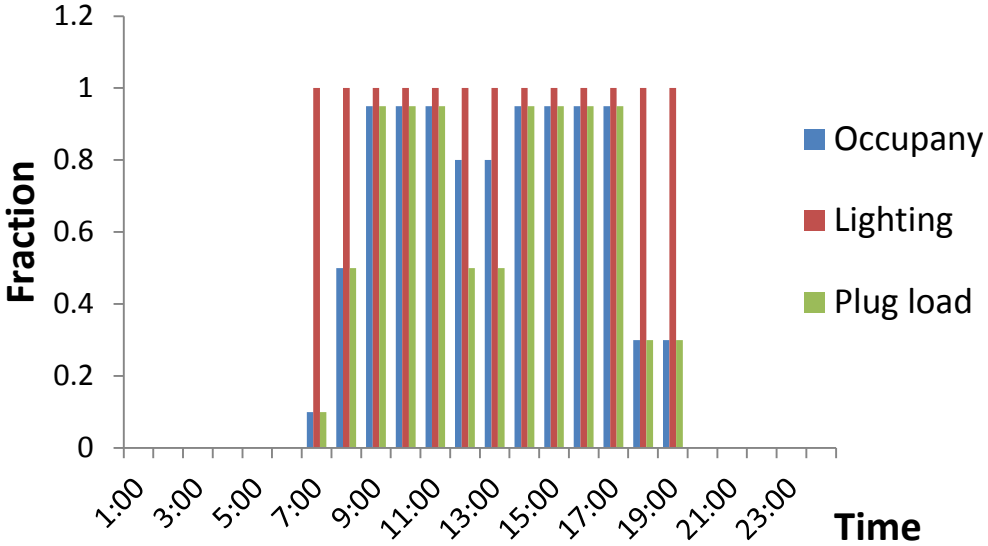
	GB50189-2005	GB50189-2014
Shape	50m * 30m	
Floors	18 floors	
WWR	0.4	
HVAC system	VAV with reheat; terminal hot water radiator (only in cold and severe cold climates)	
Lighting power density	11 W/m^2	9 W/m^2
Plug load power density	20 W/m^2	15 W/m^2
Occupancy density	8 m^3/person	
Chiller COP	4.7	5.2
Boiler efficiency	0.89	0.89
Air tightness	7.5 m^3/(m^2 hr)	3 m^3/(m^2 hr)
OA rate	30 m^3/(hr person)	
Pumps	variable speed	

- CABR collect new construction design specs from design institutes
- Reference building parameters determined by the average surveyed data

Operating conditions: big difference with ASHRAE 90.1

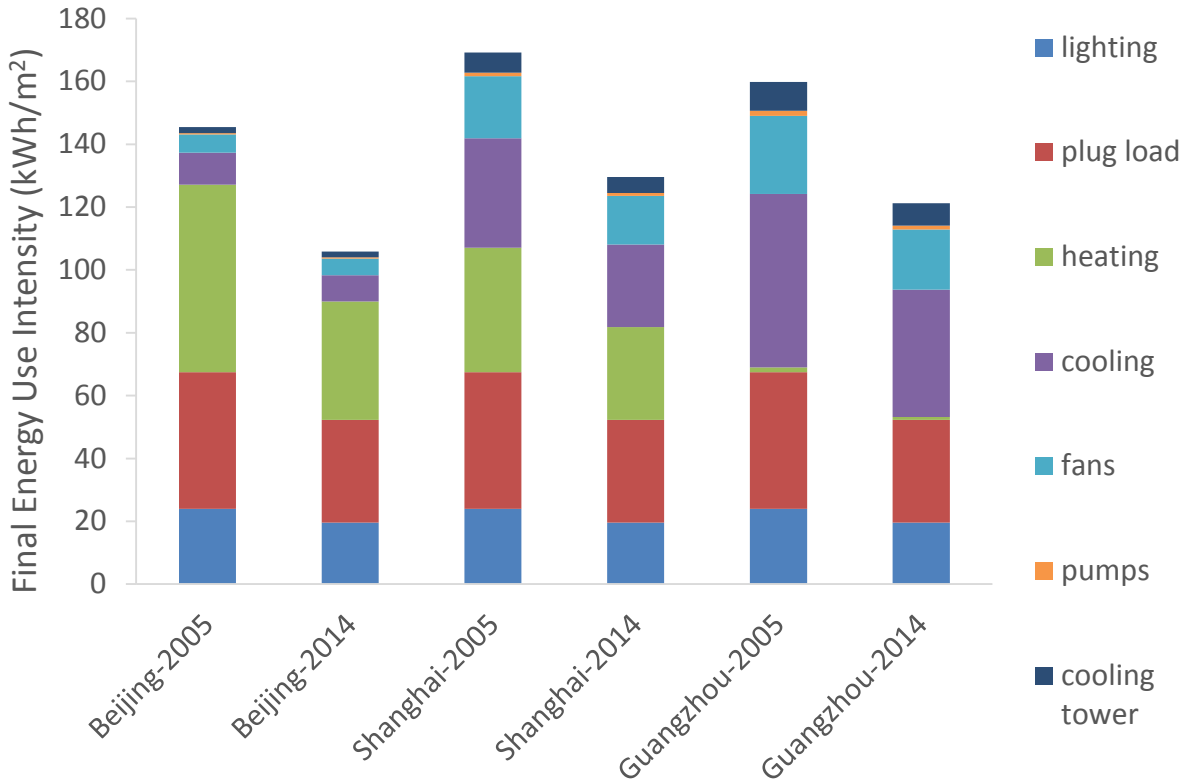
- HVAC systems are different across different climate zones
- Different thermal comfort criteria compared to ASHRAE 90.1
- Discontinuous heating and cooling operation period (e.g. district heating, in Beijing 4 months heating period)





Results: the Chinese standard performance

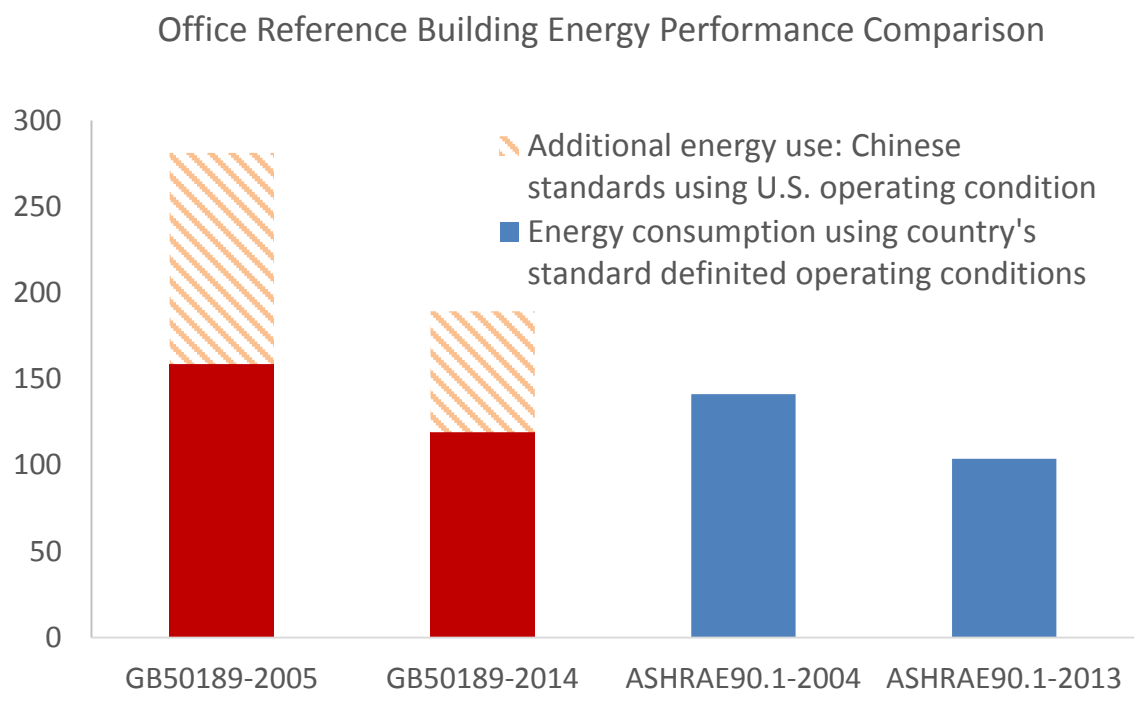
- 27%, 24%, 23% site energy savings are observed in cold, transition and warm climate respectively
- 38% heating energy savings in cold climate
- Lighting energy saving is about 18%
- Cooling energy saving is about 28% in the warm climate



-- Using Chinese operating conditions

Results: compare the standards performance between China and the U.S.

- The performance of the Chinese commercial building standard improves 25% from 2005 to 2014
- The updated Chinese standard is about 20% less efficient than ASHRAE 90.1-2013.
- Due to thermal comfort and operating condition difference, if the Chinese reference building is operated with ASHRAE conditions, its energy consumption will be higher (site EUI: ~180 kWh/m^2)



Findings: major gaps between the Chinese commercial building energy standard and ASHRAE 90.1

- Further improve building envelope performance in severe cold, cold, and hot summer cold winter climate zones.
- Include measures to encourage shading and natural ventilation for buildings in hot summer and warm winter climate zones.
- Improve commercial buildings' air-tightness level.
- Include lighting control measures in the commercial building standard.
- Include economizer requirements in the standard.
- Promote cool roof measures and encourage roof materials with high solar reflectance.
- Use appropriate measures to control chilled water temperature, supply air temperature, fan static pressure, hot water temperature, and so on.
- Encourage the installation of heat recovery devices in HVAC systems.
- Use demand-control ventilation.

2014 Achievement (Apr ~ Aug), and Next Steps

Achievement:

- Review the commercial building energy standards in China and the U.S.
- LBNL-CABR Joint development of Chinese office building
- Evaluate the new Chinese commercial building energy standard
- Compare the performance of ASHRAE 90.1 with Chinese GB-50189 and understand the gaps

Next steps:

- Evaluate the cost-effectiveness of the Chinese commercial building energy standard
- Develop more Chinese reference building types
- Evaluate the advanced Chinese commercial building standard (2015)
- Work with MOHURD to conduct code compliance and enforcement analysis

Collaboration with on building standards

- APEC working group on net/nearly zero energy building on building codes and standards
- China nearly (net) zero energy building alliance
- PNNL ASHRAE 90.1 research team

Thank You!

Question?