Research on an Energy-Efficiency Improvement Roadmap for Commercial Buildings in China

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Introduction

- To reduce the building sector's approximately 30% contribution to primary energy consumption and global warming, several developed countries have formulated Building Energy Efficiency Improvement Roadmaps (BEEIR) to guide future improvements in building energy performance.

Table 1. Building energy-efficiency targets from 11 countries

Country	Year	Building energy-efficiency target
Ireland	2013	achieve net-zero-energy building[1]
Finland	2015	implement the passive house[2] standard achieve nearly zero energy building[3]
United Kingdom	2016	zero carbon by 2016 in new residential buildings and by 2019 in new commercial buildings
Norway	2017	implement the passive house standard
Denmark	2020	reduce building energy consumption by 75% compared to 2006
France	2020	achieve positive-energy building[4]
Germany	2020	achieve zero-fossil-fuel-consumption building[5]
Hungary	2020	achieve zero emissions
Netherlands	2020	achieve energy-neutral building[6]
Japan	2020	achieve net-zero-energy building by 2020 in new commercial buildings and 2030 in all new buildings
United States	2030	achieve net-zero-energy building in new federal buildings

(A. Marszal et al. 2009, EPBD 2010, ECEEE 2014, ZHANG et al. 2013)

Introduction

► Building energy efficiency has been on China's policy agenda since the 1980s, and the energy performance of commercial buildings has improved significantly since that time.

► In early 2014, the Chinese Ministry of Housing and Urban-Rural Development (MOHURD) initiated the Building Energy-Efficiency Improvement Program (BEEIP) of research activities on which a Chinese BEEIR will be based.

► BEEIR can not only help improve the energy performance of individual buildings but also help develop the building energy-efficiency industry.
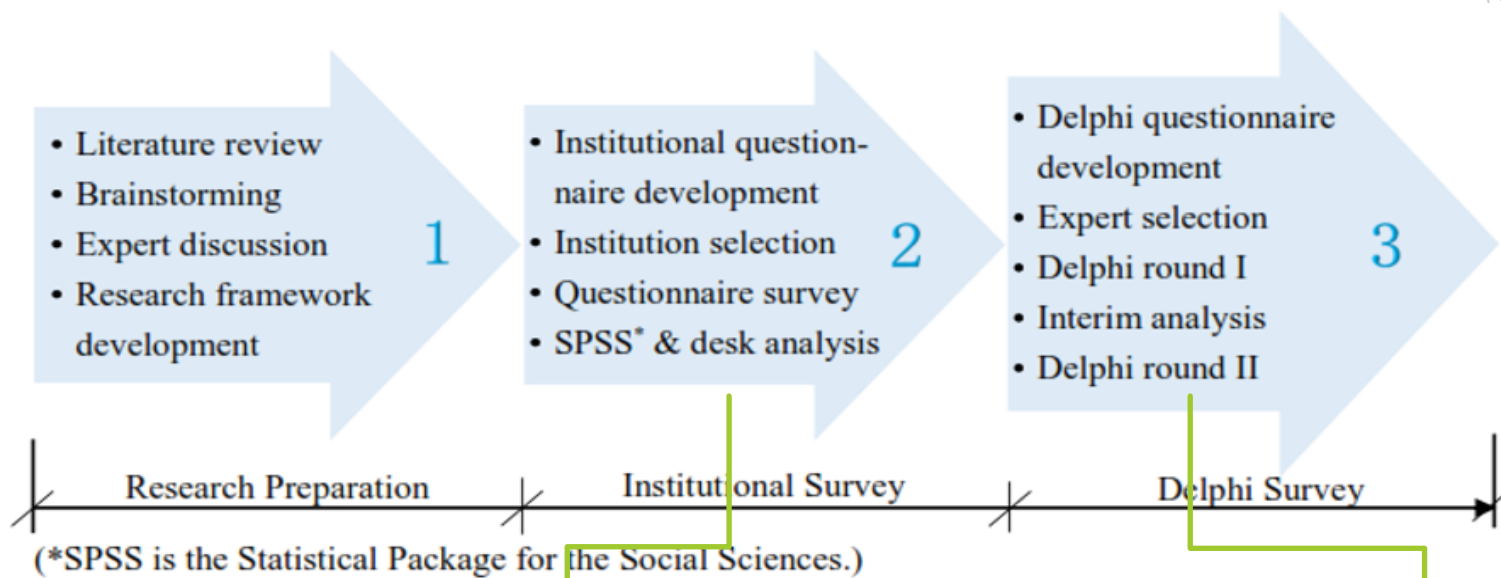
Research activities and participants

1 Research Preparation
- Literature review
- Brainstorming
- Expert discussion
- Research framework development

2 Institutional Survey
- Institutional question-naire development
- Institution selection
- Questionnaire survey
- SPSS* & desk analysis

3 Delphi Survey
- Delphi questionnaire development
- Expert selection
- Delphi round I
- Interim analysis
- Delphi round II

(*SPSS is the Statistical Package for the Social Sciences.)

Figure 1. Stages in research supporting development of China's BEEIR

- local construction adminstrative department
- building research institution
- university scientific research unit
- energy service company
- association, non-governmental organization, and others

16, 40%
13, 32%
4, 10%
4, 10%
3, 8%
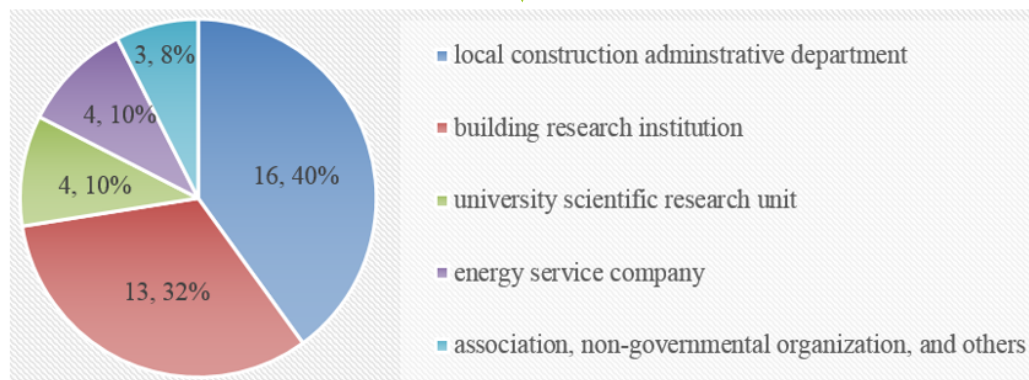
Figure 2. Institutional survey participants, by type

- senior title
- senior vice title
- intermediate title
- researcher
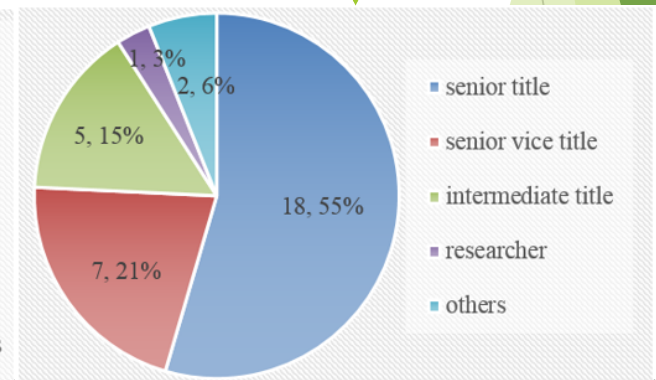- others

18, 55%
7, 21%
5, 15%
2, 6%
1, 3%

Figure 3. Delphi survey participants by job title

Results - *Factors affecting the BEEIR*
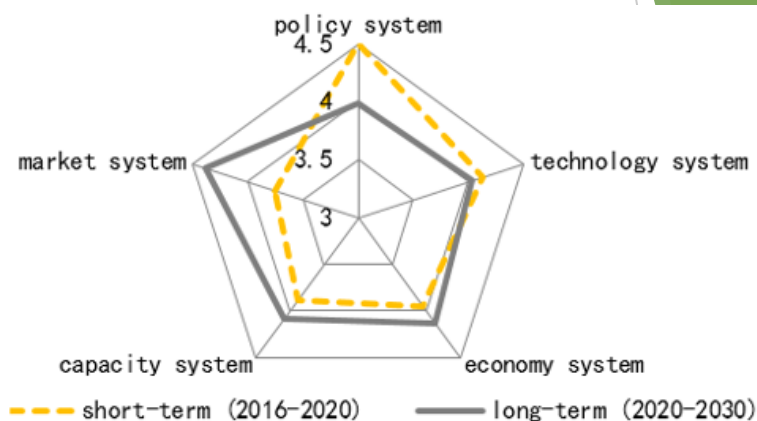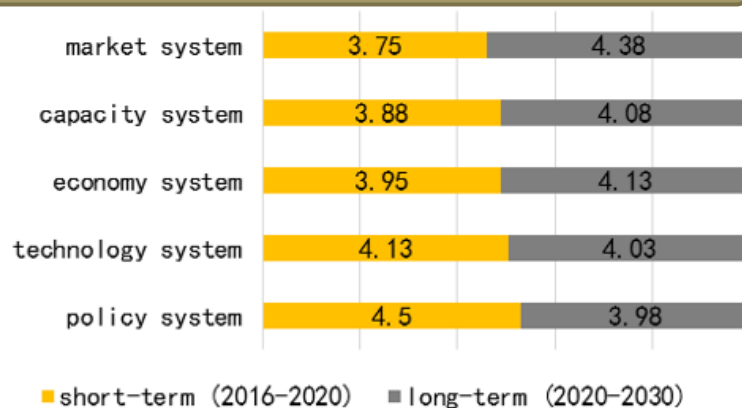
By short-term and long-term

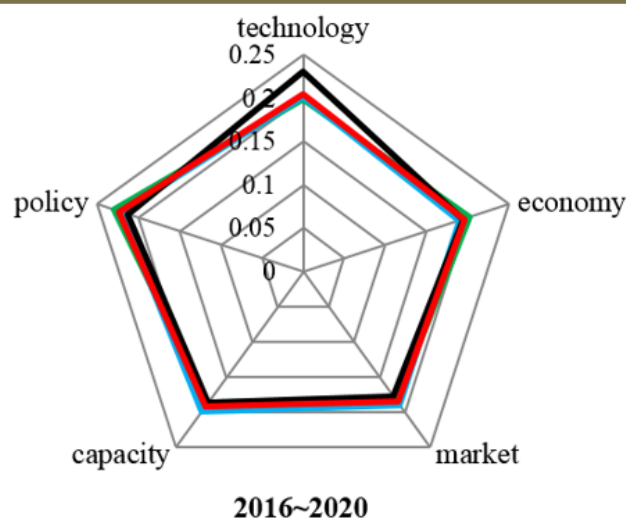Figure 4. Short- and long-term influence of five factors on the BEEIR

By different types of institutions
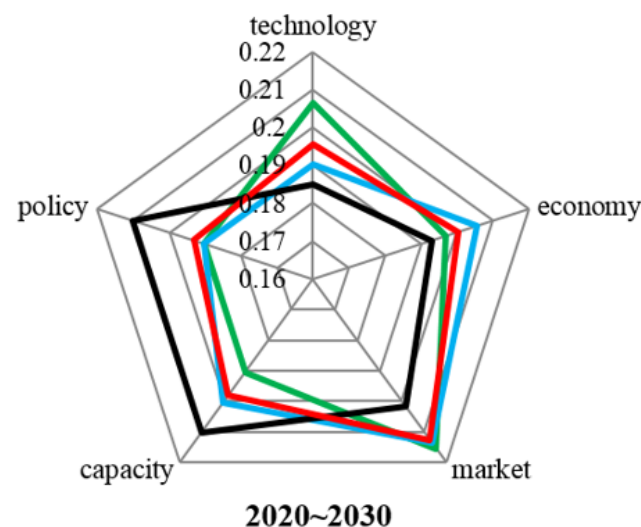
Figure 5. Weighting of factors affecting the BEEIR, as assessed by different types of institutions

Results - *The Roadmap*

Figure 6. Three phases of China's BEEIR (2016-2030)

▶ The initial state was set in 2016 to synchronize with the start of the 13th FYP and to allow for one year's preparation from the time the research was completed.

▶ The intermediate state is set in 2020, which corresponds to the start of the 14th FYP.

▶ And the BEEIR vision was projected to be achieved in 2030.

Efficiency targets for new commercial buildings

Table 2. Efficiency levels for new commercial buildings in target years 2016-2030

| Year | BEEIR new commercial-building energy-efficiency improvement targets | | |
	Institutional Survey	Delphi survey round 1	Delphi survey round 2
2016	62% energy-efficiency design standard; GB★*	65% energy-efficiency design standard; GB★	latest energy-efficiency design standard (GB 50189-2015, 62% energy efficiency); GB★ in government public buildings & large (floor area ≥ 20,000 m²) commercial buildings
2020	GB★★*	75% energy-efficiency design standard; GB★★	reduce energy consumption based 20% compared to 2016 (about 70% more efficient than 1980s' baseline); renewable energy supplies no less than 10% of total building energy consumption; HVAC** energy consumption decreased 30% compared to 2016 baseline; all commercial buildings with floor area ≥5,000m² should meet current minimum GB standards
2030	Nearly-zero-energy building (nZEB)	HVAC energy consumption ≤ 15kWh/m²·a (≈5.7kgce)	reduce energy consumption 30% compared to 2020 (about 79% more efficient than 1980s' baseline); renewable energy supplies no less than 20% of the total building energy consumption; achieve nZEB*** level with HVAC site energy consumption ≤ 15kWh/m²·a (≈5.7kgce); all commercial buildings with floor area ≥2,000m² should meet current minimum GB standard requirements

*GB: Green Building. GB★ is the Chinese GB standard lowest (one-star) of the standard's three levels, and GB ★★ is the middle level.

**HVAC: Heating, ventilation, and air conditioning

***nZEB: Nearly-zero-energy building

Site energy consumption 15kWh/ m²·a≈5.7kgce, is converted using the 2013 electricity consumption baseline.

Table 3. Efficiency levels for existing commercial buildings in target years 2016-2030

| Year | BEEIR existing commercial-building energy-efficiency improvement targets | | |
	Institutional Survey*	Delphi survey round 1*	Delphi survey round 2
2016	10% energy-efficiency improvement	20% energy-efficiency improvement	establish regional commercial-building energy-consumption quotas
2020	20-30% energy-efficiency improvement	40-50% energy-efficiency improvement	reduce energy consumption by 20% compared to 2016 quota; implement green updates in whole-building retrofits & meet current energy-consumption quota; implement regional commercial-building energy-efficiency design standards in partial retrofits
2030	implement green update	70% energy-efficiency improvement; implement green update	reduce energy consumption by 50% compared to 2016 quota (35% decline compared to 2020 quota); implement green updates in whole-building retrofits & meet current energy-consumption quota; implement regional commercial-building energy-efficiency design standards in partial retrofits

*For existing commercial buildings, the energy-efficiency improvement baseline for columns 2 (institutional survey) and 3 (Delphi survey round 1) is the energy performance before retrofit.

Results –
Performance indicators

▶ Performance indicators are important for defining and quantifying the progress toward meeting the BEEIR goals.

▶ Influenced by the Chinese GB rating, we developed an indicator system that encompasses not only energy consumption but also other green and ecological elements (the GB rating includes not only energy efficiency but also water and materials efficiency, indoor environment enhancement, and waste reduction).

▶ These elements were organized into three categories: healthy and comfortable quality of life, least resource consumption, and minimal environmental impact. They were further broken down into sub-indicators with specific values that become increasingly strict from 2020 to 2030.

Table 4. BEEIR status indicators for 2020 (intermediate stage)

Field	Indicator	Value	Institution survey A*	Institution survey B*	Delphi round 1 A	Delphi round 1 B	Delphi round 2 A	Delphi round 2 B
Healthy and comfortable quality of life	indoor temperature and humidity	cold and severe cold zone: the average temperature in winter should be about 20℃, temperature in summer not higher than 26℃, and the relative humidity 40%-60%	—	—	■	■	■	■
		hot summer and cold winter zone: temperature in winter not lower than 18℃, temperature in summer not higher than 26℃	—	—	■	■	■	■
		hot summer and warm winter zone: temperature not higher than 26℃ year round	—	—	■	■	■	■
	indoor acoustic environment	window closed: ≤ 45 dB (daytime); & ≤ 35dB nighttime)	■	■	■	■	■	■
	indoor lighting environment	meet standard for lighting design of buildings (GB 50034-2013)	■	■	■	■	■	■
	indoor air quality	meet code for indoor environmental pollution control of civil building engineering (GB 50325-2010); CO_2 concentration ≤ 1,000PPM	■	■	■	■	■	■
	public facilities	elevator, fire control, accessibility, etc.	■	■	■	■	■	■

(to be continued)

Category	Item	Requirement	1	2	3	4	5	6
Least resource consumption	building energy-efficiency level	meet year-2020 BEEIR requirements	—	—	—	—	■	■
	non-traditional water utilization	≥ 30%	—	—	—	—	■	■
	waste-heat utilization	can be counted as alternative to conventional energy and calculated into energy savings	—	—	—	—	■	■
	HVAC energy consumption	< 15kWh/ m²•a	■	—	—	—	—	—
		< 60kWh/ m²•a	—	—	■	—	■	—
	circulating-water utilization	> 50%	■	—	■	—	■	—
	new & renewable-energy utilization	in regions with accessible renewable-energy resources, renewable energy utilization ratio ≥ 10% of total building energy consumption	—	—	—	—	■	■
		in regions with accessible renewable-energy resources, renewable energy utilization ratio ≥ 12% of the total building energy consumption	■	—	■	—	■	—
Minimal environmental impact	carbon-emissions baseline	establish carbon-emissions baseline of commercial-building sector	■	—	■	—	■	■
	construction-waste recycling	≥ 30%	—	—	—	—	■	■
	harmful substances emissions		■	■	■	—	■	—

*"A" is the new-commercial-building sector; "B" is the existing-commercial-building sector.

(The End)

Table 5. BEEIR status indicators for 2030 (vision stage)

Field	Indicator	Value	Institution survey A*	B*	Delphi round 1 A	B	Delphi round 2 A	B
Healthy and comfortable quality of life	indoor temperature and humidity	same as 2020 (Table 4)	—	—	■	■	■	■
	indoor acoustic environment	same as 2020 (Table 4)	■	■	■	■	■	■
	indoor lighting environment	same as 2020 (Table 4)	■	■	■	■	■	■
	indoor air quality	in addition to contents shown in Table 4, daily average PM2.5* concentration ⩽ 30micrograms per cubic meter	■	■	■	■	■	■
	public facilities	same as 2020 (Table 4)	■	■	■	■	■	■
Least resource consumption	building energy-efficiency level	meet BEEIR year-2030 requirements	—	—	—	—	■	■
	non-traditional water utilization	⩾ 50%	—	—	—	—	■	■
	waste-heat utilization	same as 2020 (Table 4)	—	—	—	—	■	■
	HVAC energy consumption	≈0	—	—	■	—	—	—
		< 15kWh/ m²·a	—	—	■	—	■	—

(to be continued)

The year 2030 (vision stage)-2

Field	Indicator	The year 2030 Value	Institution survey A*	Institution survey B*	Delphi round 1 A	Delphi round 1 B	Delphi round 2 A	Delphi round 2 B
Least resource consumption	circulating-water utilization	same as 2020 (Table 4)	—	—	■	—	■	—
	new & renewable-energy utilization	in regions with accessible renewable energy resources, renewable energy utilization ratio ≥ 20% of the total building energy consumption	—	—	—	—	■	■
		use more renewable energy than 2020	■	—	—	—	—	—
		renewable-energy utilization ratio ≥ 30% of total building energy consumption	—	—	■	—	■	—
Minimal environmental impact	carbon-emissions baseline	decrease carbon emissions baseline 20% based on 2020	—	—	—	—	■	■
	construction-waste recycling	100%	—	—	■	—	■	■
	harmful substances emissions	≈0	■	—	■	—	■	—

*"A" is the new-commercial-building sector; "B" is the existing-commercial-building sector; PM2.5 is 2.5-micron particulate matter.

（The End）

Conclusions and recommendations

▶ Three milestones of the BEEIR:

  ✓ the baseline status in 2016

  ✓ an intermediate more efficient status in 2020

  ✓ full achievement of the BEEIR vision in 2030

▶ The indicator system, aiming at help quantify progress under the BEEIR, is more comprehensive and environmentally friendly, address:

  ✓ energy efficiency

  ✓ water efficiency

  ✓ materials efficiency

  ✓ indoor environmental quality

  ✓ other related areas

▶ All of the five factors– technology, economy, market, capacity, and policy – are influential in both the short and long term. Indicates that China needs to comprehensively strengthen these five elements to provide robust support for the BEEIR.

Thank You !

Q & A ?