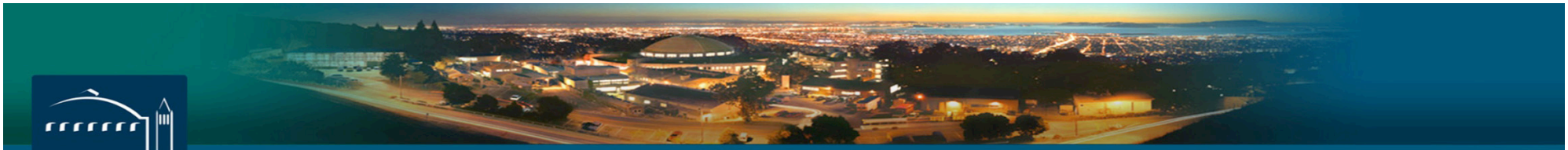

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From Prescriptive to Outcome-Based —The Evolution of Building Energy Codes and Standards in China

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Outline

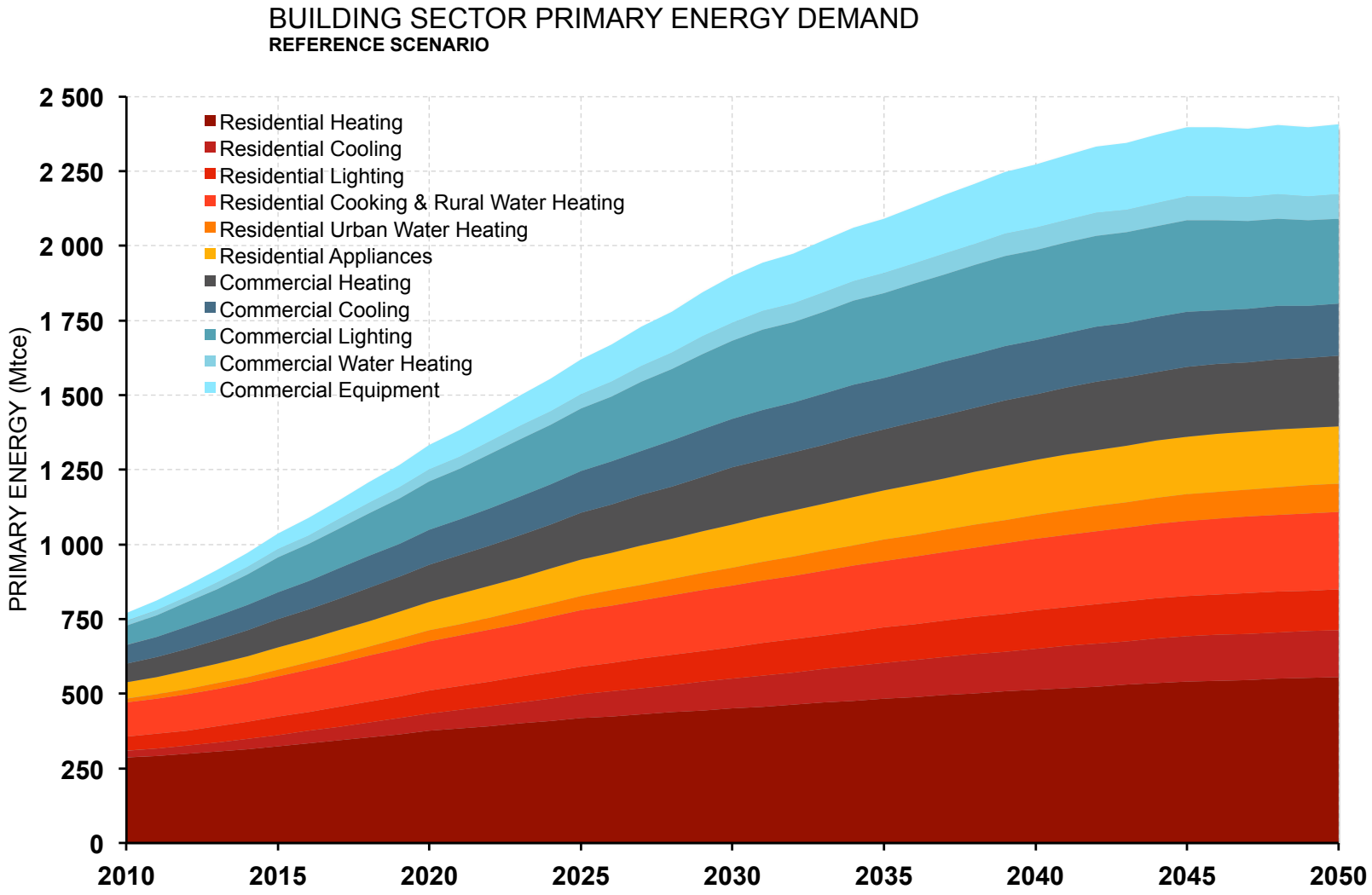
- Background
- Review
- Chinese standards analysis
- Conclusions

Background

- Buildings consume ~20% primary energy in China
- Energy use in building sector is estimated to continue growing due to increasing income level and living and comfort conditions.
- Existing building energy standards for commercial buildings (2015) and residential buildings only prescribe design measures for new construction
- Regulate design measures doesn't necessarily yield low operation energy in buildings.
  - Prescriptive and performance-based standards are often applied to permit new construction but not often used in existing buildings.
  - Prescriptive and performance-based standards tend to focus more on energy conservation measures and model energy performance, than on the actual energy use.
  - There are "unregulated measures" which are difficult to regulate through the prescriptive and performance-based standards

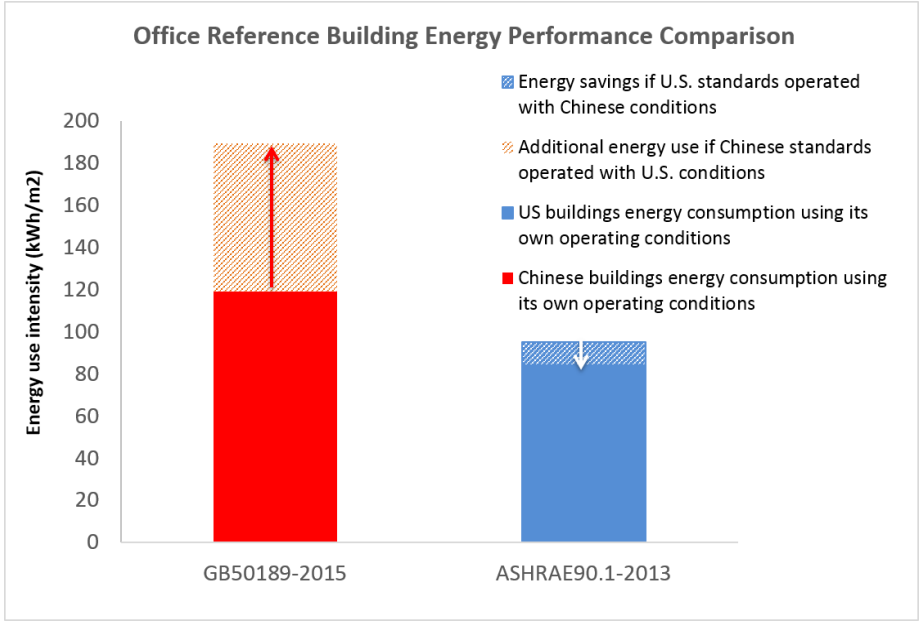
Background

- Increasing energy demand in the future in China's building sector

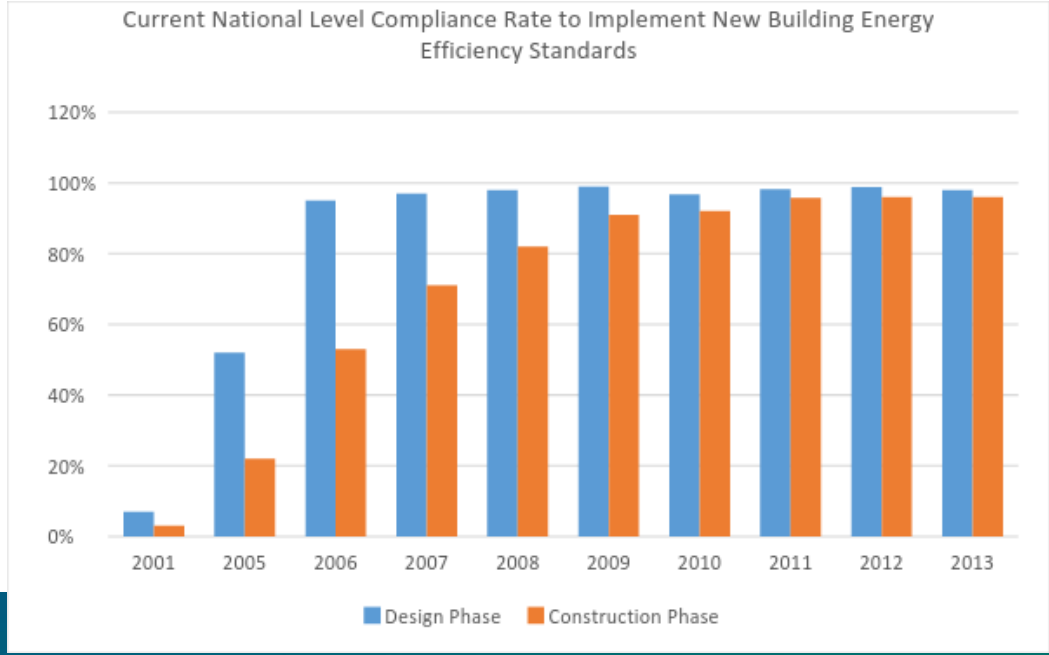


Background

- Prescriptive standards efficiency levels have been improved in the past, but still demonstrates significant caps with U.S. standards



- Compliance rate for implementing energy efficiency standards in China has been improved over time.



This paper's contribution

- *Review international best practices for developing outcome-based energy codes and standards and provide recommendations for the new Chinese outcome-based energy standard.*

- *Evaluate the technical performance of the Chinese outcome-based standard target settings by comparing them to prescriptive energy standards.*

City of Seattle

- Adopted in 2012
- Site energy target settings
- voluntary, alternative pathway for compliance
- working with pilot buildings, collecting their actual operation energy performance.
- A building needs to be continuously operated for at least 12 months and to have 75% or more of its space occupied during that operation period.
- Outcome-based target setting is modelled on city-level benchmarking and disclosure data, but the actual EUI settings are selected with much lower EUI.
- Sub-metering systems are desirable to acquire detailed building energy use information
- conduct energy modelling first to demonstrate savings opportunities, then sensitivity analysis is required to quantify the impacts of operation measures
- Incentive programs are effective to promote the adoption of the outcome-based codes and demonstrate energy savings beyond code requirement

Building type	EUI target - kWh/m^2 (or kBtu/ft^2)
B- occupancy office	126 (or 40)
B-occupancy medical office	157.5 (or 50)
R-2 occupancy multifamily	110 (or 35)
S-1 and S-2 occupancy warehouse	78.7 (or 25)
E-occupancy school	141.7 (or 45)
M-occupancy retail	189 (or 60)
I-2 occupancy hospital	472.5 (or 150)
Parking garages	31.5 (or 10) for enclosed garages; 18.9 (or 6) for open garages

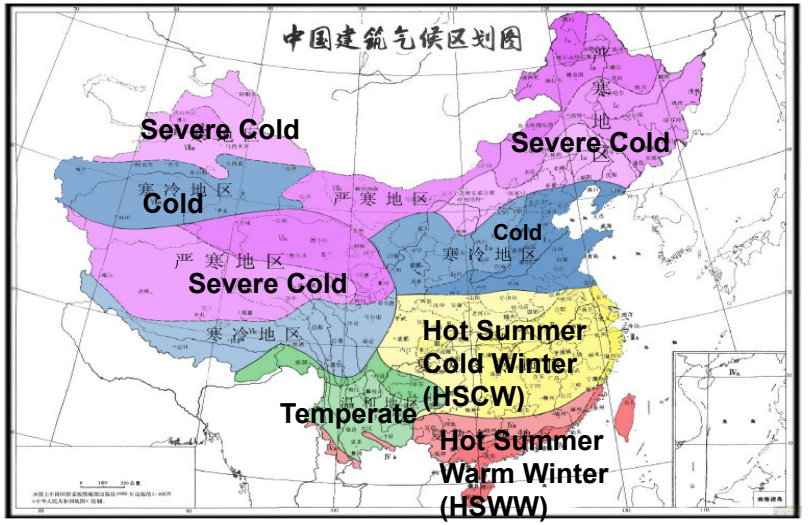
Sweden

- Stated in 2006
- Site energy target settings
- Prescribe energy use intensity based on buildings are electrically heated or non-electrically heated.
- EUI includes heating, ventilation, and hot water but not plug loads and lighting
- requires buildings to verify its performance within 24 months of its completion with continuous monitoring data for 12 months.
- Differentiates building types on target EUI settings: small houses, small houses with conditioned floor space less than 50m^2, apartment buildings, apartment building blocks with conditioned space larger than 50m^2, ordinary non-residential buildings, and small non-residential buildings with conditioned floor space less than 50m^2
- allows buildings to calculate their relative performance based on outdoor air different ventilation rates
- provides a set of policies for building compliance, including commissioning, permitting, fines to fail to compliance, and so on.

Climate Zone	EUI target for non-electric heating - kWh/m^2	EUI target for electric heating - kWh/m^2
Climate zone 1	105	85
Climate zone 2	90	65
Climate zone 3	70	50
Climate zone 4	65	45

China

- Adopted in 2016
- Mixed primary and site energy target settings
- Two target value settings: Mandatory value and recommended value.
- Includes district heating EUI targets for different type of district heating types: city level, community level, and single building level.
- District heating in the North China has separated EUI targets in unit kgce/m^2, and not included in building EUI targets in the Northern Chinese climate zones in 3 categories above. Can be normalized by HDD numbers.
- Prescribes building heating load intensity in the North China climate zones in unit GJ/m^2.
- Prescribes heating energy transportation system efficiency (pipeline + HX, also pump energy) in 3 categories above
- However, heating energy is included in buildings' total EUI targets for buildings in the HSCW and HSWW climate zones.
- Residential buildings EUI targets (exclude North China district heating) is separately specified for 5 climate zones, and can be normalized by occupant # per household (table right).



Climate zone	Electric EUI target [kWh/（a • h）]	Natural Gas EUI target [m^3/（a • h）]
Severe cold	2200	150
Cold	2700	140
HSCW	3100	240
HSWW	2800	160
Temperate	2200	150

China

- For commercial, has two categories:

-- Cat. A buildings with distributed HVAC

-- Cat. B large size commercial buildings with centralized HVAC

- Exclude heating North China climate zones
- Specifies targets for different buildings types:
  - Office (government & commercial)
  - Hotel (3, 4, 5-star)
  - Retail (grocery store, shopping mall, supermarket, restaurant, general shop)
- Parking garages have separated targets
- Target can ben normalized by:
  - Operating hrs (office, retail)
  - Occupant density (office)
  - Lodging rate (hotel)
- Non-electric heating should be back converted to electric energy intensity using 0.320kgce/kWh or 0.2 Nm^3/kWh in order to compile with the targets

Building	Category	Type and scale	EUI in Hot Summer Cold Winter Climate zone (Shanghai) – kWh/m^2	
			Required value	Recommended Value
Office	Cat. A	Government office	70	50
		Commercial office	85	70
	Cat. B	Government office	90	65
		Commercial office	110	80
Hotel	Cat. A	3-star or lower	110	90
		4-star	135	115
		5-star	160	135
	Cat. B	3-star or lower	160	120
		4-star	200	150
		5-star	240	180
Retail	Cat. A	General store	130	110
		Shopping center	130	110
		General supermarket	150	120
		Restaurant	90	70
		General shop	90	70
	Cat. B	Large store	200	170
		Large shopping mall	260	210
		Large supermarket	225	180

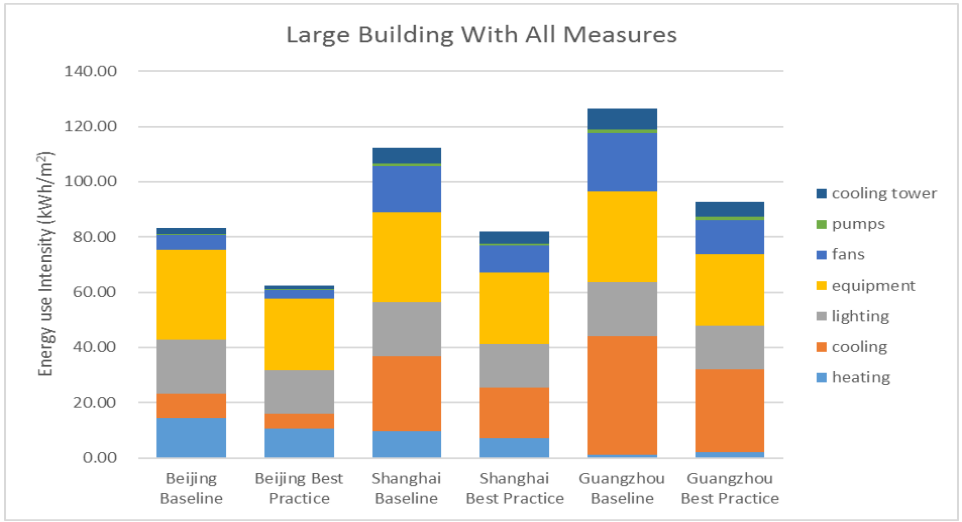
A Research Question

- Question: how the targets setting of the Chinese outcome based standard is in line with the well-established prescriptive energy efficiency standards?

- Solution: developed reference buildings and identified key operation conditions impact building energy use and conduct sensitivity analysis.

Performance Analysis

- Two reference office buildings (small, large)
- Three major climate zones (Beijing, Shanghai, Guangzhou)
- Prescriptive measures complied with Chinese commercial building energy efficiency standard GB/T 50189-2015
- A set of operation measures:
  - Heating and cooling setpoint adjustment
  - Occupant based lighting and equipment controls
  - Natural ventilation
  - Window shading controls
  - Air-side economizer controls
  - Chilled water supplied temperate reset



	Beijing		Shanghai		Guangzhou	
	Small	Large	Small	Large	Small	Large
Cooling system	Package AC	AHU VAV + Chiller + Boiler	DX coil	AHU VAV + Chiller + Boiler	DX coil	AHU VAV + Chiller + Boiler
Heating system	Radiator + Boiler		Electric Coil		Electrical Coil	
Equipment density (W/m2)	15	15	15	15	15	15
Lighting density (W/m2)	9	11	9	11	9	11
Window U value (W/m2-K)	2.7	2.7	3	3	3.5	3.5
Window SHGC	0.59	0.59	0.42	0.42	0.336	0.336

Performance Analysis -- Findings

- Changing operation conditions can help buildings significantly reduce actual energy use
- With optimal operation conditions and controls, office buildings complied with prescriptive standards can achieve the required target settings mandated by the outcome based energy standard
- Some recommended target settings are difficult to achieve and need further investigation

	Operation conditions	Beijing		Shanghai		Guangzhou	
		Savings, kWh/m2	Savings ratio	Savings, kWh/m2	Savings ratio	Savings, kWh/m2	Savings ratio
Small Office Building	cooling setp	0.61	0.75%	0.81	1.12%	0.11	0.17%
	heating setp	2.8	3.47%	2.98	4.13%	0.59	0.92%
	lighting use	3.86	4.78%	4.12	5.70%	4.36	6.74%
	equip use	6.27	7.76%	6.35	8.80%	6.9	10.67%
	natural ventilation	1.01	1.25%	7.68	10.64%	1.18	1.82%
	shading	0.2	0.25%	0.11	0.15%	0.16	0.24%
Large Office Building	cooling setp	1.38	1.66%	11.86	10.57%	17.81	14.09%
	heating setp	3.17	3.81%	3.58	3.19%	3.94	3.12%
	lighting use	4.43	5.33%	7.23	6.44%	9.16	7.25%
	equip use	7.17	8.63%	10.85	9.67%	13.01	10.29%
	Natural Ventilation	10.71	11.62%	14.19	12.10%	14.87	10%
	shading	0.77	0.93%	3.27	2.91%	4.63	3.66%
	economizer	0.34	0.41%	2.36	2.10%	4.06	3.22%
	SA reset	1.15	1.38%	2.34	2.08%	3.96	3.13%

	Baseline	Best practice	Outcome-based required target		Outcome-based recommended target	
			Government office	Commercial office	Government office	Commercial office
Small office (Cat A)	72.19	53.82	70	85	50	70
Large office (Cat B)	112.22	81.82	90	110	65	80

Comparison between China, Seattle, and Sweden

	China	Sweden	City of Seattle
Physical boundary of energy balance	Varies. Has both building-scale and outside of building scale i.e. heating in Northern China (district heating). Primary energy for heating and site energy for non-northern China heating. Separate electricity and natural gas energy use in residential buildings.	A building's own site energy	A building's own site energy
Targets EUI definition	EUI (kWh/m2) for commercial buildings, and per household energy density for residential buildings; also includes matrix for district heating system.	EUI (kWh/m2) for all building types.	EUI (kWh/m2) for all building types.
Target categories	Two EUI values: required value and recommended value; distinguish buildings with operable windows (Cat. A), and non-operable window (Cat. B).	Distinguish electric heating and non-electric heating.	Single value.
Building type	Commercial and residential. Commercial includes office, retail, and hotel and further division of each building type. Parking garage is separate.	Residential and all non-residential buildings.	Commercial buildings: office, medical office, school, hospital, warehouse, retail, and parking garage.
Data measurement period	One year of data.	One year data, 24 months after completion of construction.	12 moths continuous monitoring within 3 years of building's occupation.
End Use Coverage	All end use,	Only heating, ventilation, and hot water.	All end use,
Performance normalization or sensitivity analysis	Can be normalized by occupancy rate, operating hours, hotel guest room floor space ratio, and number of persons per household.	Can be normalized by outdoor air ventilation rate.	Sensitivity analysis based on occupant density, lighting power, plug load, infiltration rates, and temperature setpoints.

Conclusions

- Chinese outcome based energy standard has very comprehensive target settings
- Different energy boundaries have been mandated in the Chinese outcome based energy standards
- The technical target settings are in general in line with the prescriptive standard's requirement. However some recommended targets are very low and difficult to achieve.
- Operation conditions are effective to help buildings complied with prescriptive standards meet with outcome based energy standard
- Significant amount of work would be required to harmonize the two standards and document the compliance procedures for new buildings to achieve both prescriptive standards in design stage and then outcome-based standard in the operation stage. Not only in technical requirements but also policies for promoting compliance.
- Unclear about how to use the outcome based standard for existing buildings
- Supporting policies are needed for the outcome based standards:
  - Incentive and disincentive policies are still needed to promote adoption of the standard. e.g. security funds from building owners
  - The current outcome-based standard does not clarify how data should be collected and reported, especially with the given complex data boundaries and end use level requirements aforementioned, and how buildings energy performance should be measured and verified.
  - A national data disclosure and benchmarking program needs to be established to help China better define energy performance targets and rules for sensitivity analysis and performance normalization.

Thank You!

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