The approach for low-carbon buildings in China and developing countries

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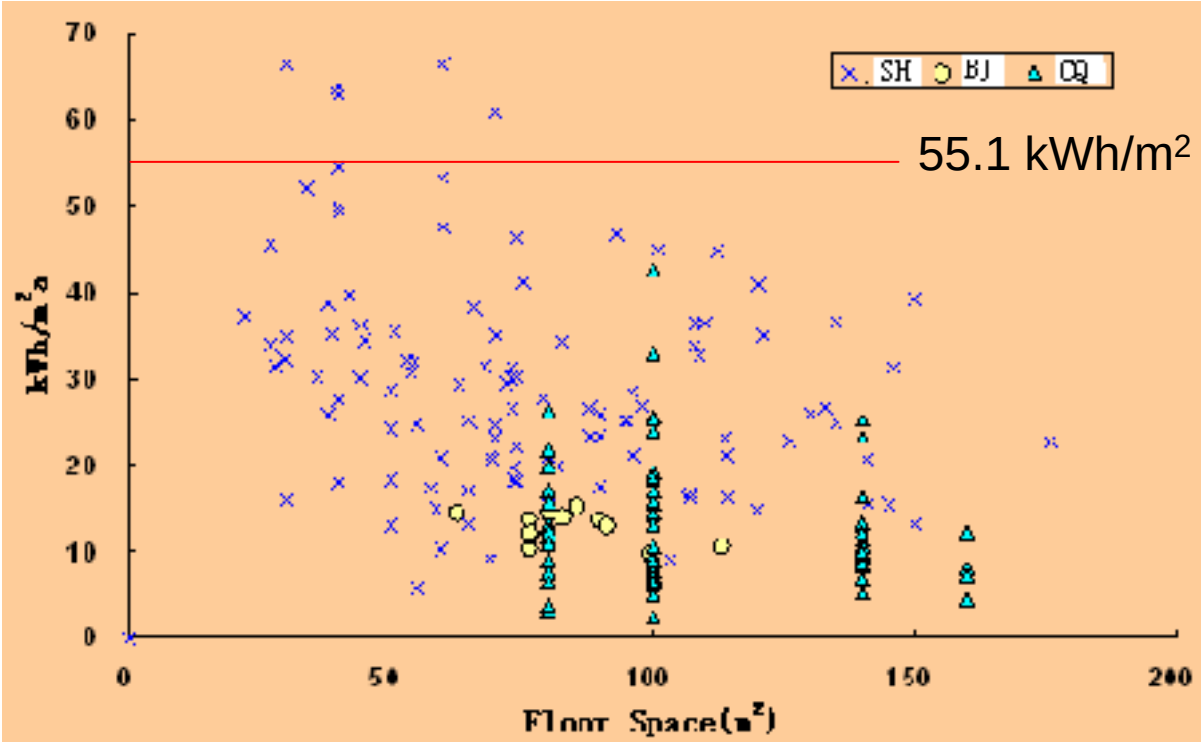
Case study: Shanghai BEC code

- For residential building the electricity for heating and cooling shall be less than 55.1 kWh/m^2.year as an energy efficiency building
- The 55.1 kWh/m^2.year is based on energy simulation under the conditions:
  - Well insulated building
  - HVAC 24 hours operation
  - Indoor temperature is within 18 ~ 25 ℃
  - 0.5 time of volume per hour of air infiltration all time

What happens in real buildings?



Electricity consumption of residential buildings
In Shanghai, Beijing & Chongqing

Electricity use in residential buildings

City	kWh/m^2.a	purposes
Beijing	24.3	AC, lighting & apparatus
Suzhou	31.2	Heating, cooling Lighting & apparatus
Shenyang	21.7	AC, lighting & apparatus

Electricity consumption for residential buildings in three cities

AC energy consumption in Beijing

A. 5 floors, 1981, 74m^2/unit
Split unit

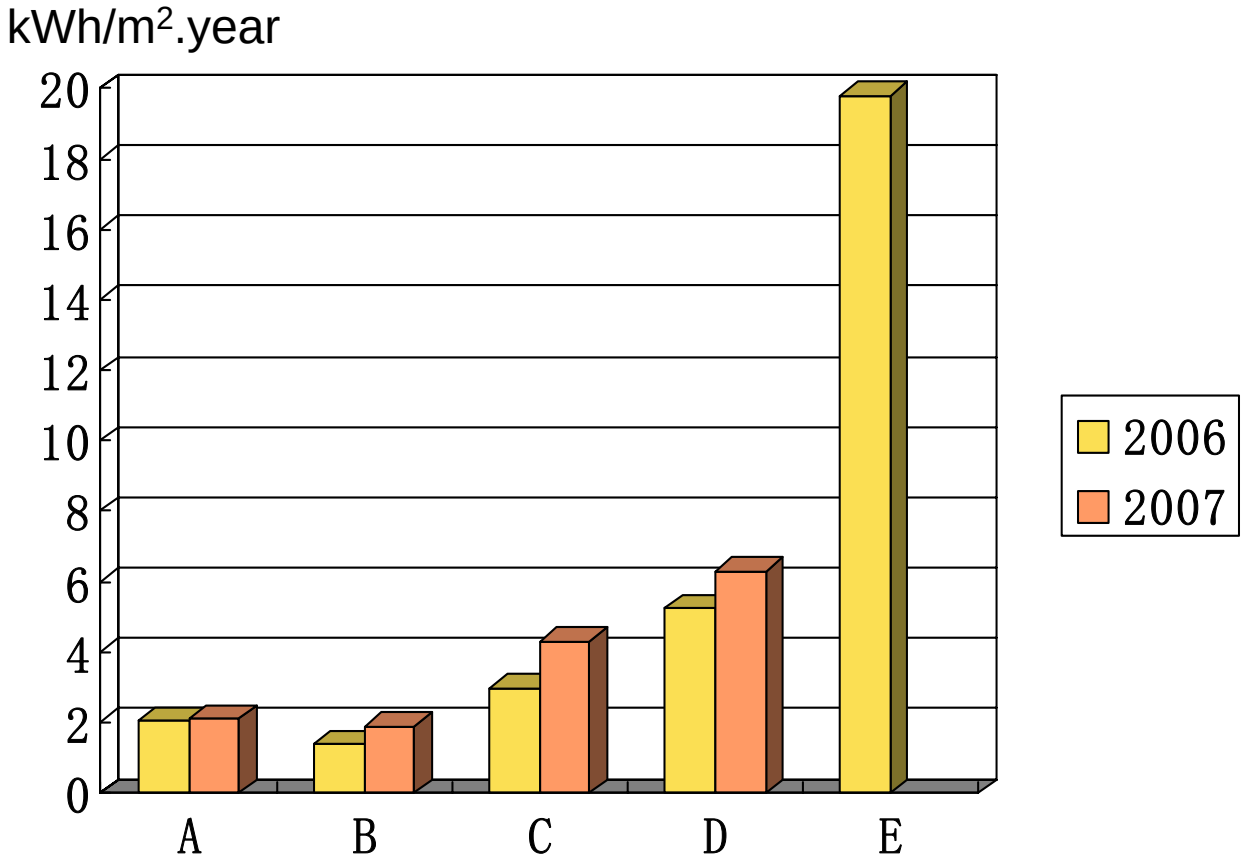
C. 26 floors, 2003, 141m^2/unit
Split unit

D. 26 floors, 2004, 132m^2
one outdoor & multi
indoor units

B.18 floors, 1996, 103m^2/unit,
Split unit

E. 26 floors, 2005, 280 m^2/unit
Central AC system

AC energy in 5 buildings, Beijing

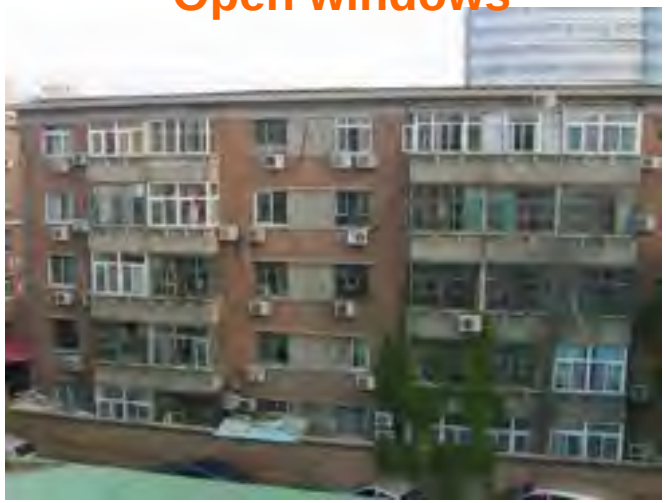


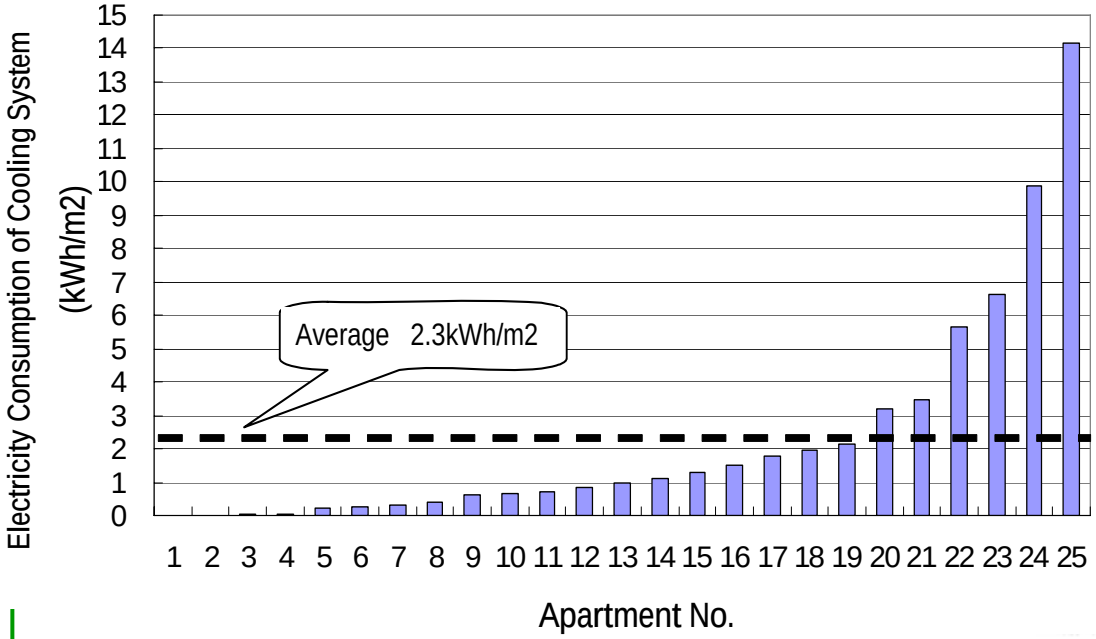
The average electricity consumption for different buildings: kWh/m^2.year

Case study: AC in Residential buildings

- **The measured energy consumption of AC in every units of a residential building in Beijing,2006, split unit**

Key reason:
Part time
Part space
Open windows





Centre AC for residential buildings in Beijing: 19.8 kWh/m²,a

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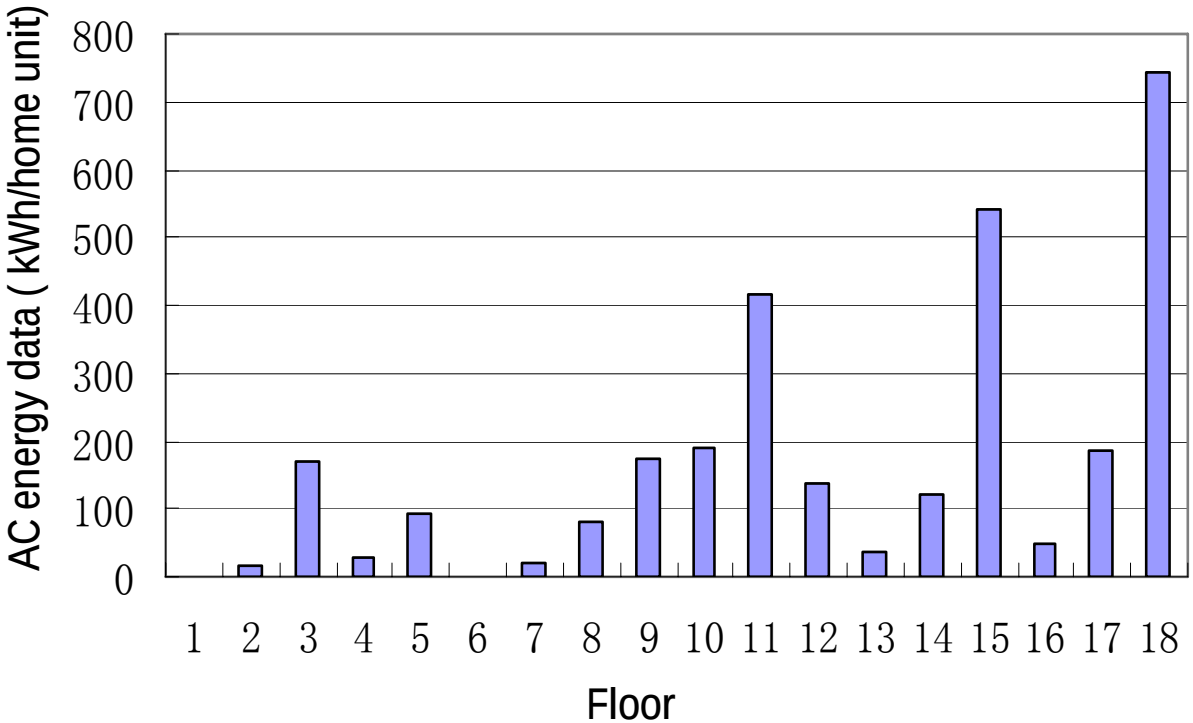
Case study: AC in Residential buildings



Electricity consumption by AC for home units
at same location but different floors in building B

Where the different come from?

- **The major reason: different operation hours**

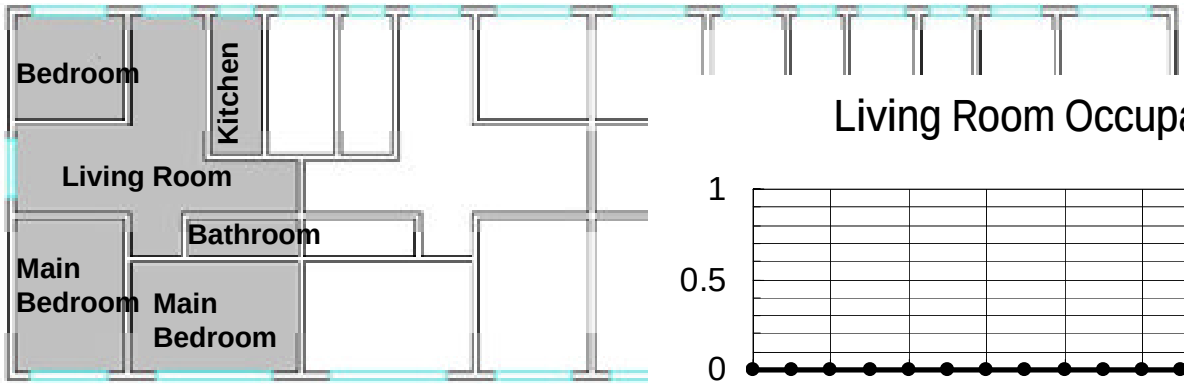
- **Why people operate the AC in different ways?**
  - **Building component: very weak**
  - **Income level: very weak**
  - **Age of the family: highly correlated**

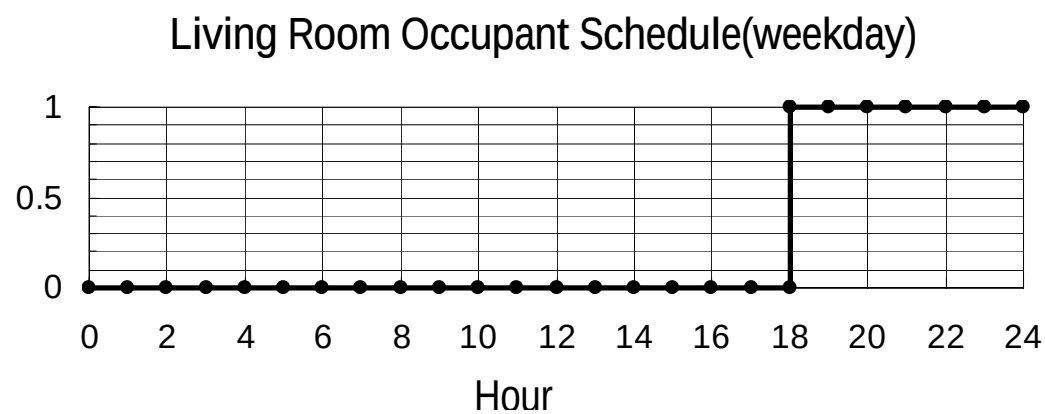
Study the reason of the differences by simulation

- **Why the operation schedule are so different?**
  - Set point of temperature
  - Part space occupied & operated
  - Part time operation
  - Open windows for ventilation when outside is fair
  - Different in indoor casual gain

Energy prediction with different usages

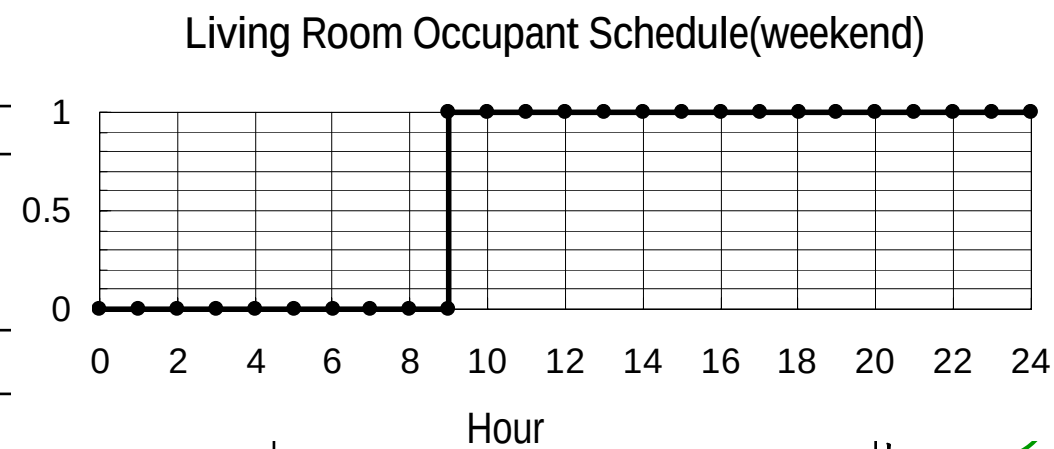
- **A normal residential flat in Shanghai**





- **List of the parameters**
  - **Coefficient**
  - **Interior heat gains**

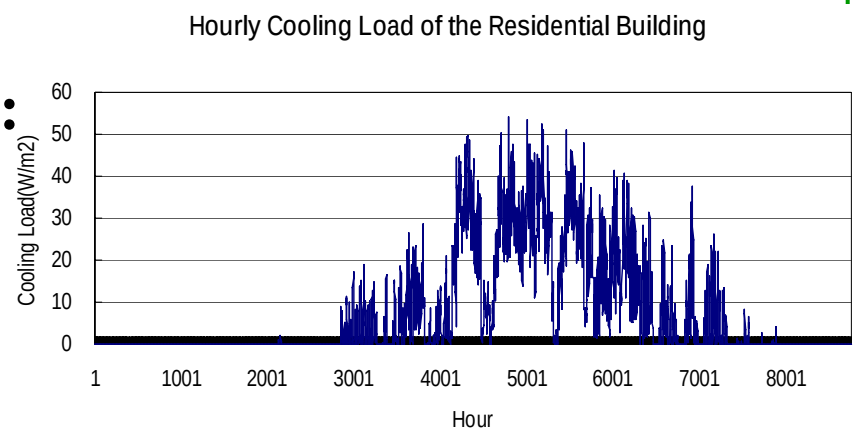
	Exterior wall	
	Maximum person density （Person/room）	
Living Room	3	
Bedroom	2	



Reference case

Standard case:

- Room temperature control: 18~25 ℃
- HVAC operation:24 hours
- Ventilation: 1/hr air infiltration
- Cooling area: full space



Simulation result

- Average cooling electricity consumption:21.8kWh/m2·a
- Heating need 35kWh/m2.a

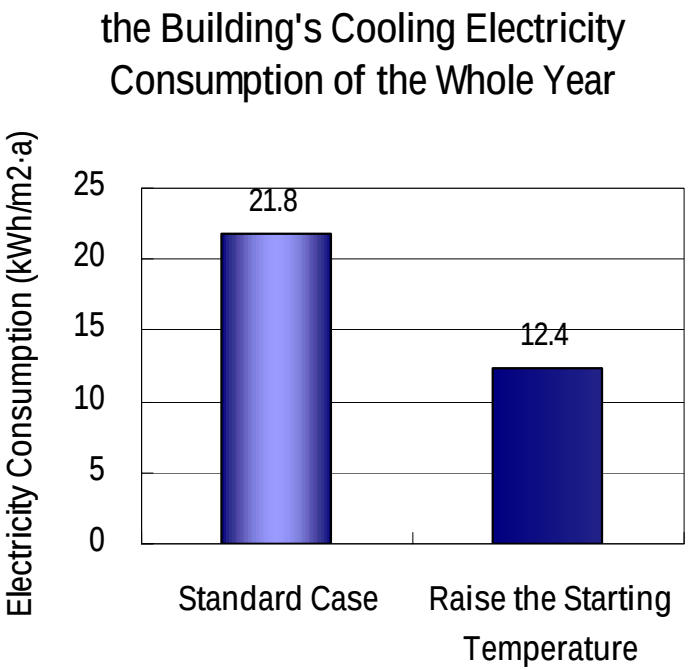
What should be the set point?

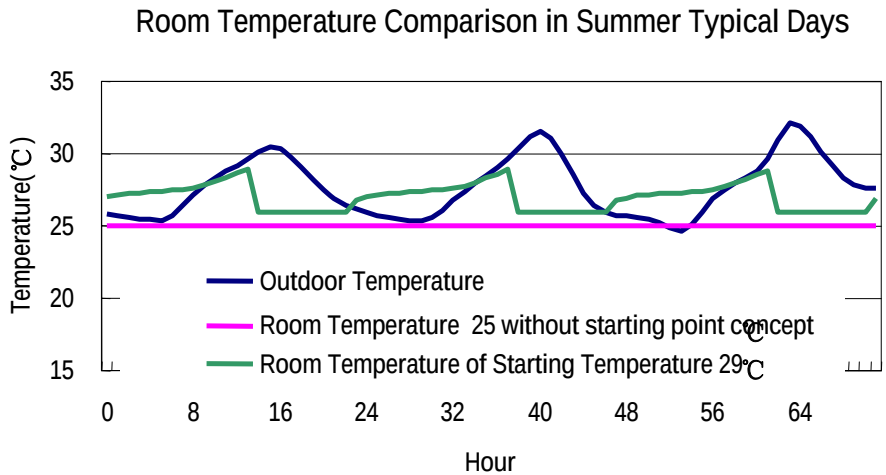
- **Starting temperature:**
  - as soon as indoor temperature is lower than the starting point, occupant may not turn on the AC even it is higher than comfort set point
  - However, After the AC is turned on, it is very likely that the occupant keeps the indoor at the comfort set point

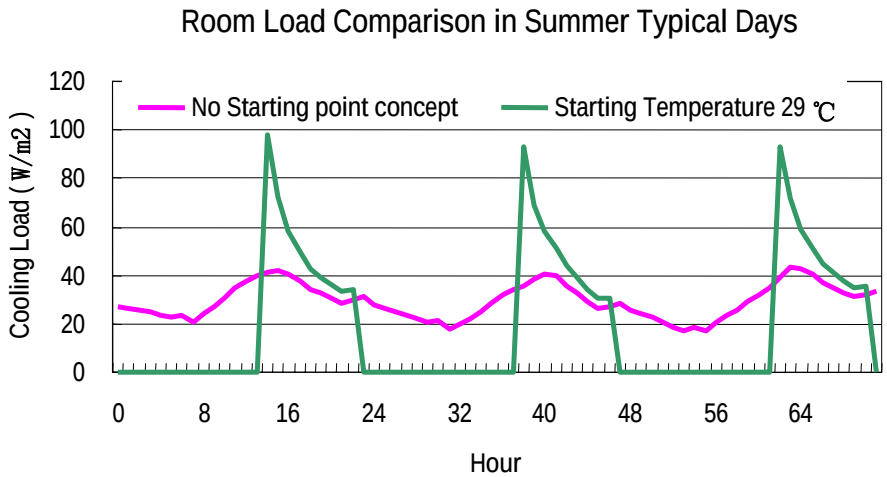
- **From measured data**
  - room temperature of residential buildings with AC system in Beijing

- **Simulation Case2:**
  - Starting temperature: 29 ℃
  - Comfort set point: 26℃

result with “Starting point” concept







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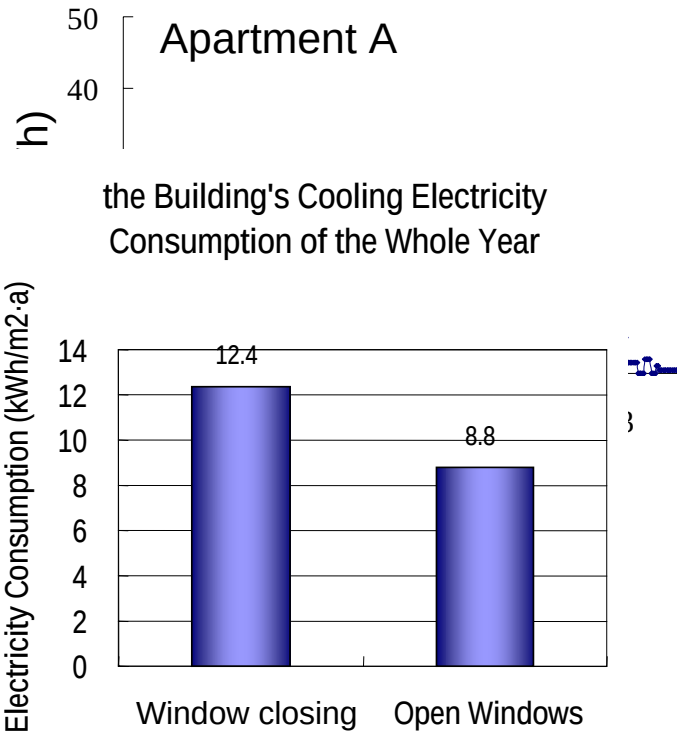
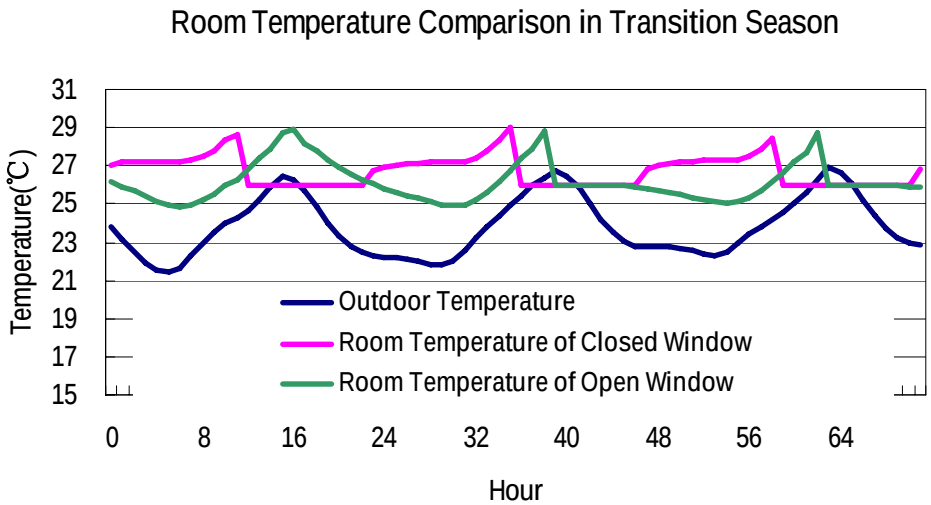
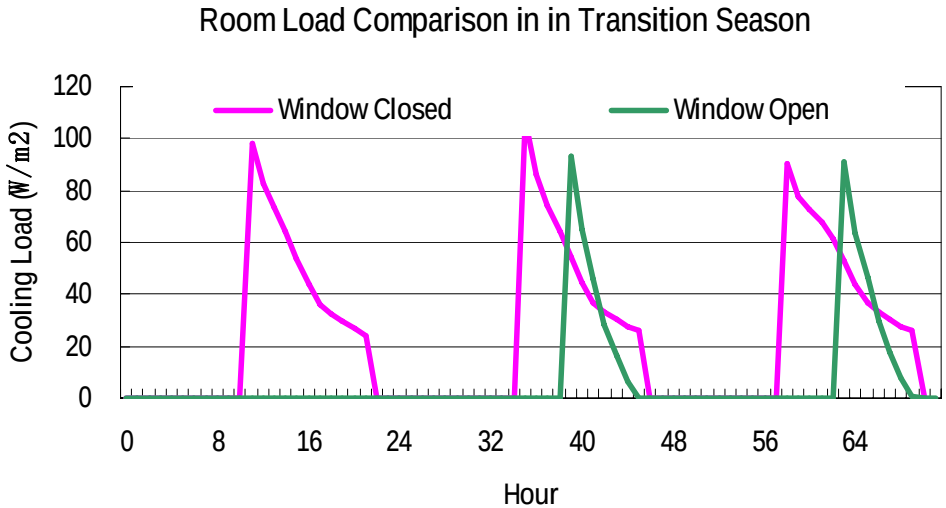
What is the different if open windows?

- **Measured data**
  - **Data of natural ventilation in a residential flat**
- **Simulation Case2:**



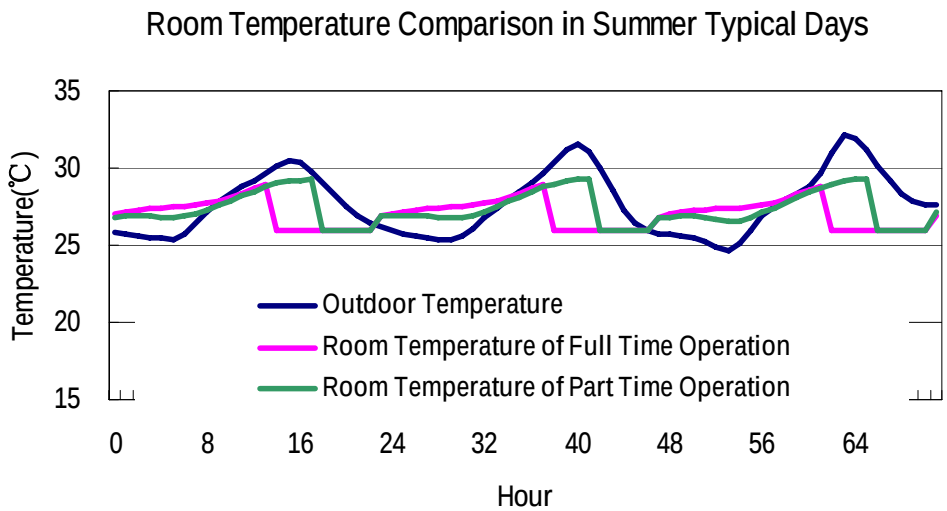


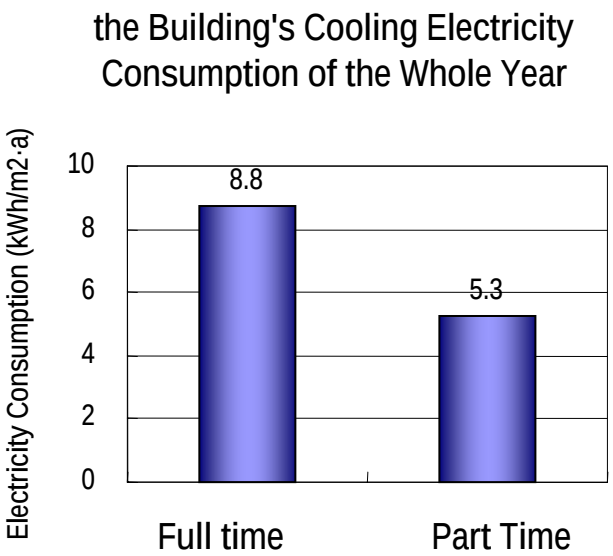


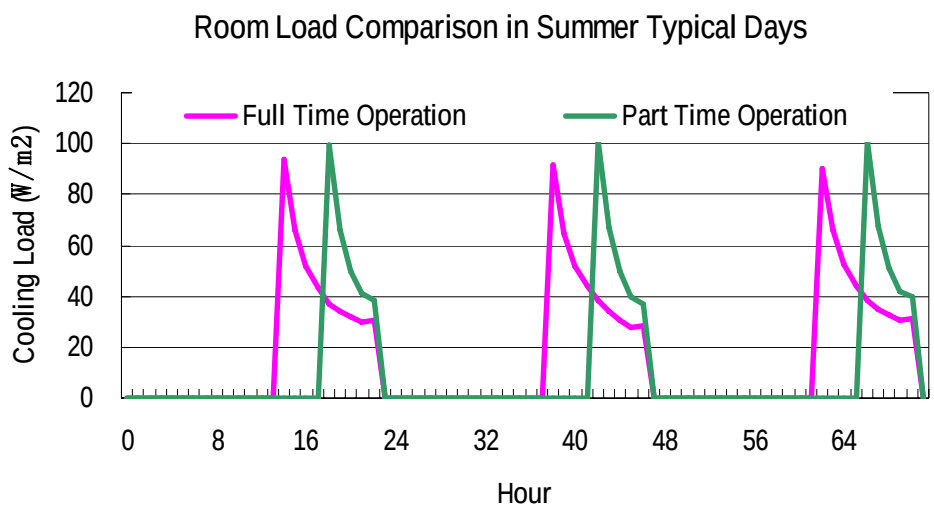
If Part time operation?

Simulation Case4:

- AC operations from 18:00~23:00



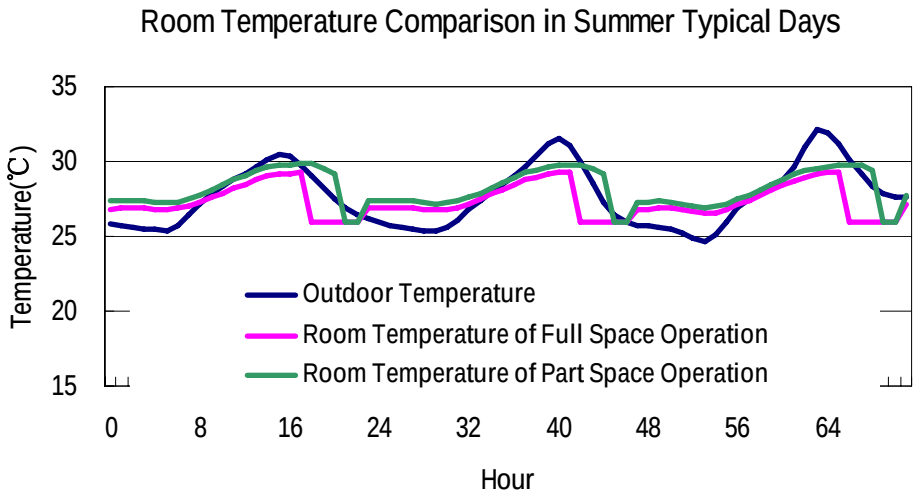


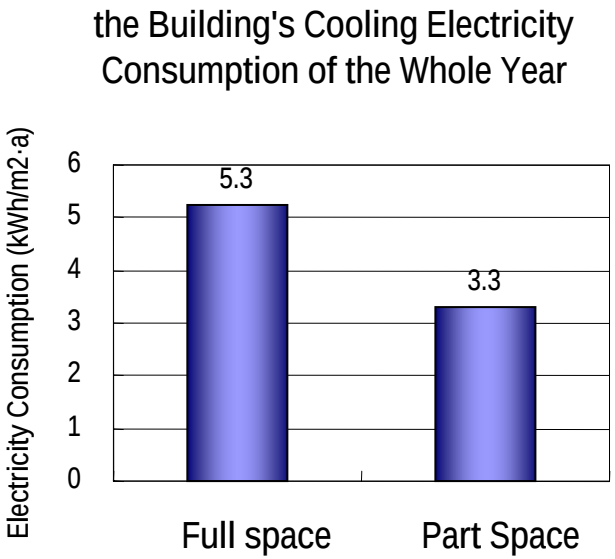


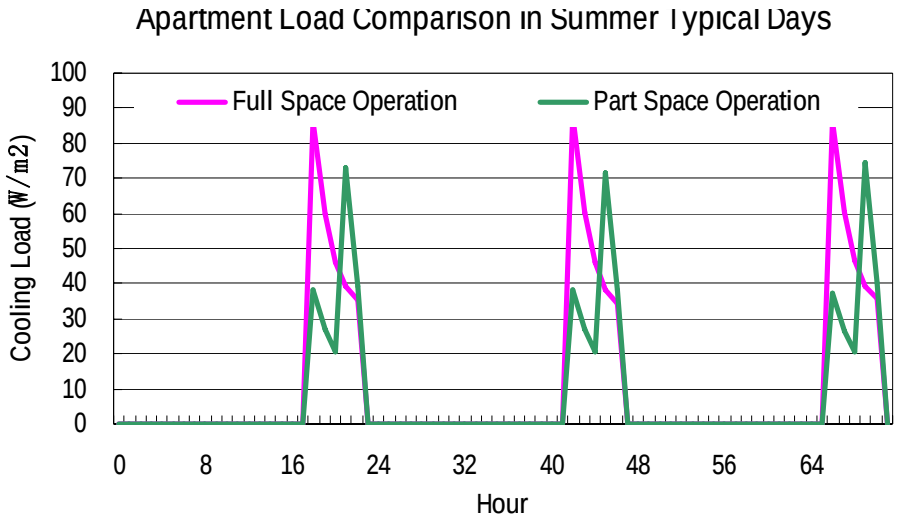
If part space operation?

Simulation Case5:

- 18:00~21:00 sitting room only
- 22:00~23:00 bed room only
- 21:00~22:00 both sitting room & bed room

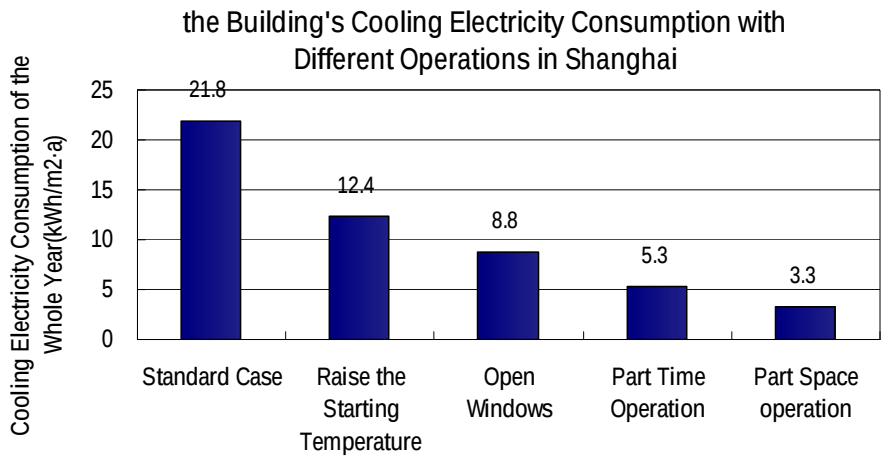




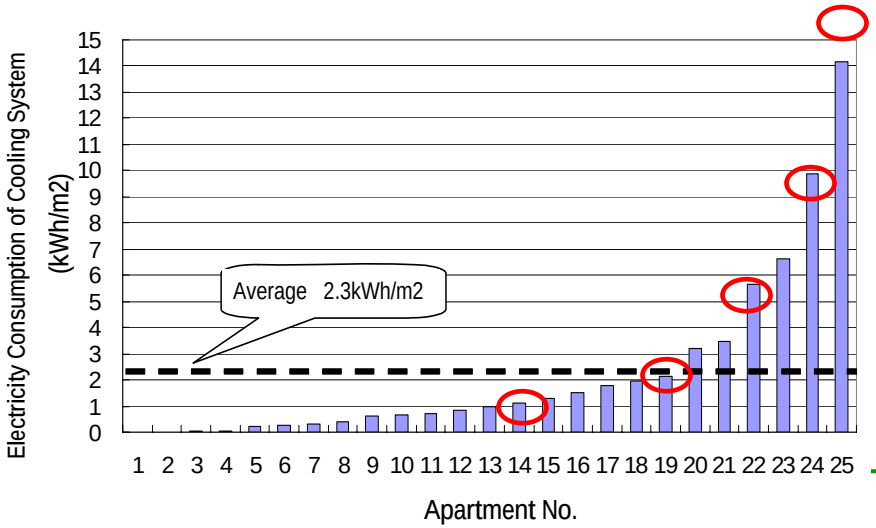


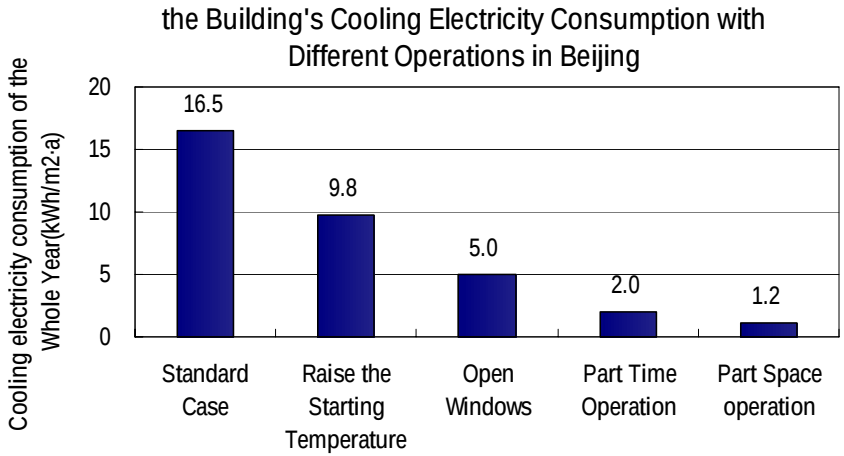
How energy relate with operation?

- **Comparing with the energy consumption of the five cases**
  - **Total cooling electricity consumption: 21.8kWh/m^2 to 3.3kWh/m^2!**



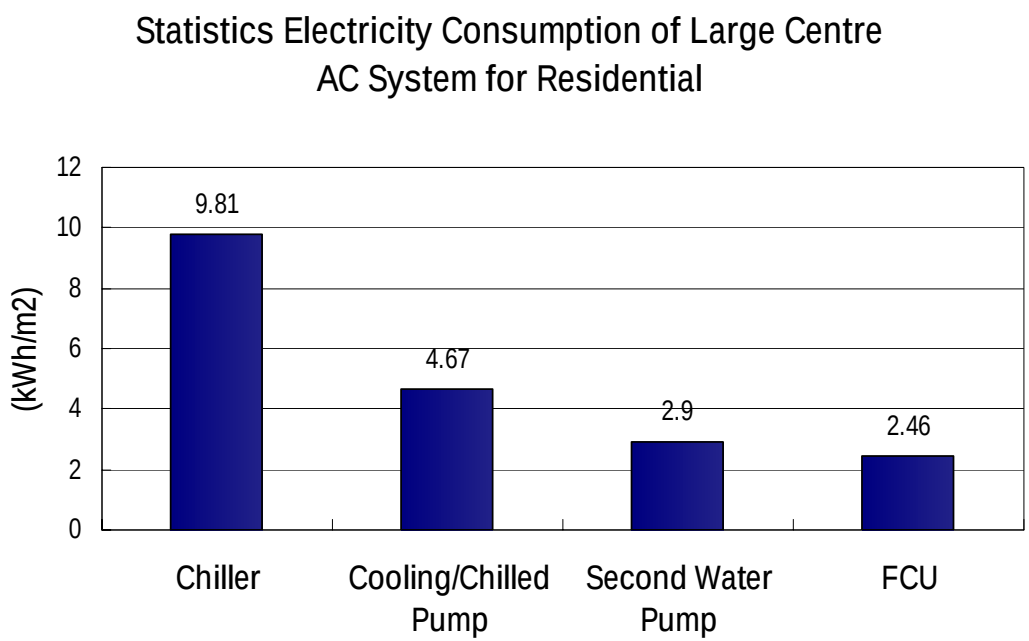
- **Measured data & simulation data in Beijing**





What we have learnt ?

- **Opening windows, part time & part space operation can make huge difference in energy**
- **Should we apply large centre AC system for residential?**



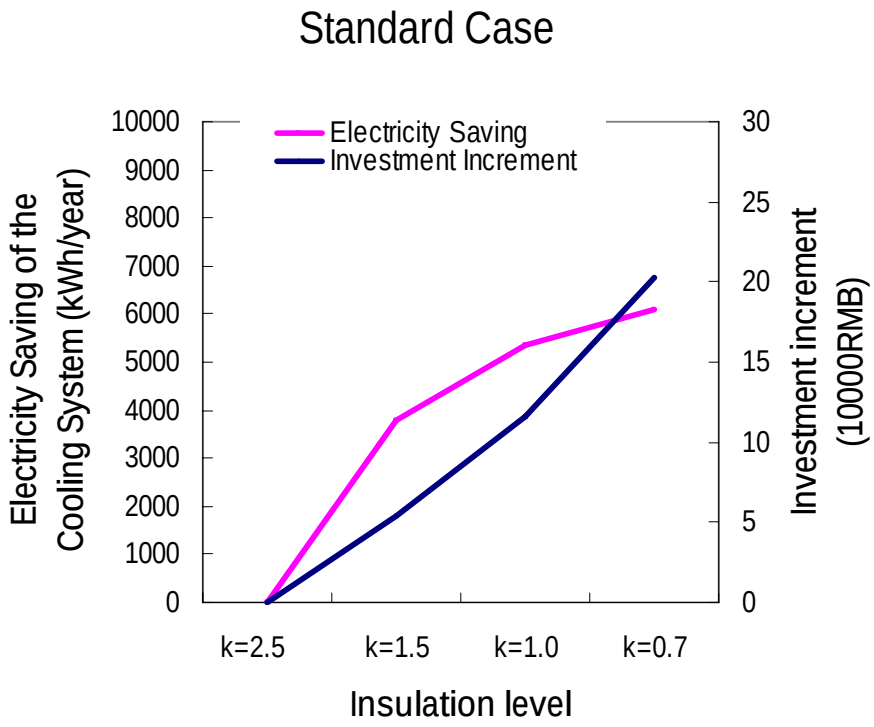
Large centre AC system: 20kWh/m^{2}a
Average decentralized AC system:2.3kWh/m^{2}a

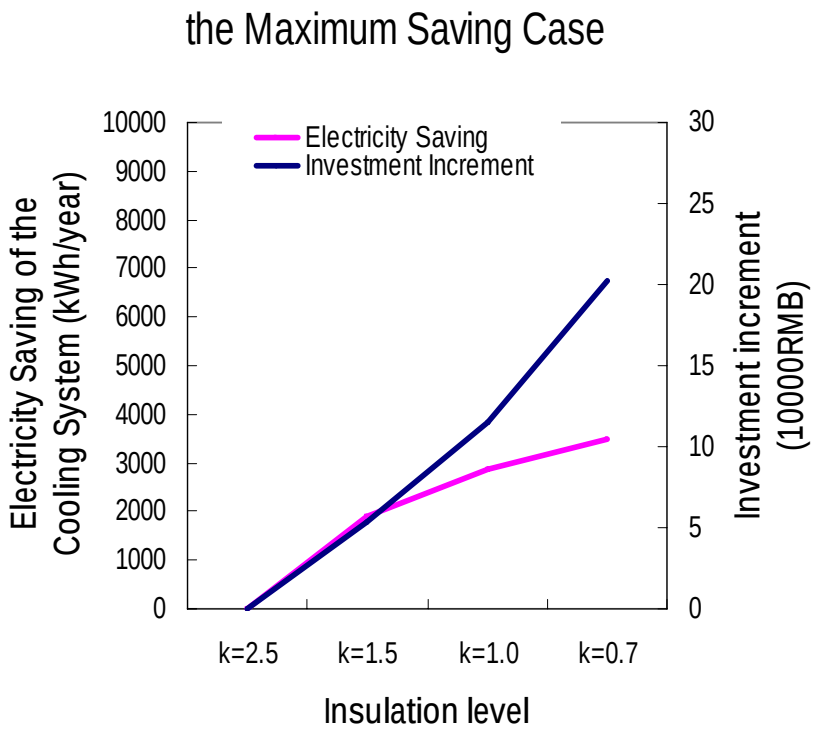
10times!

Operation manner & building optimization

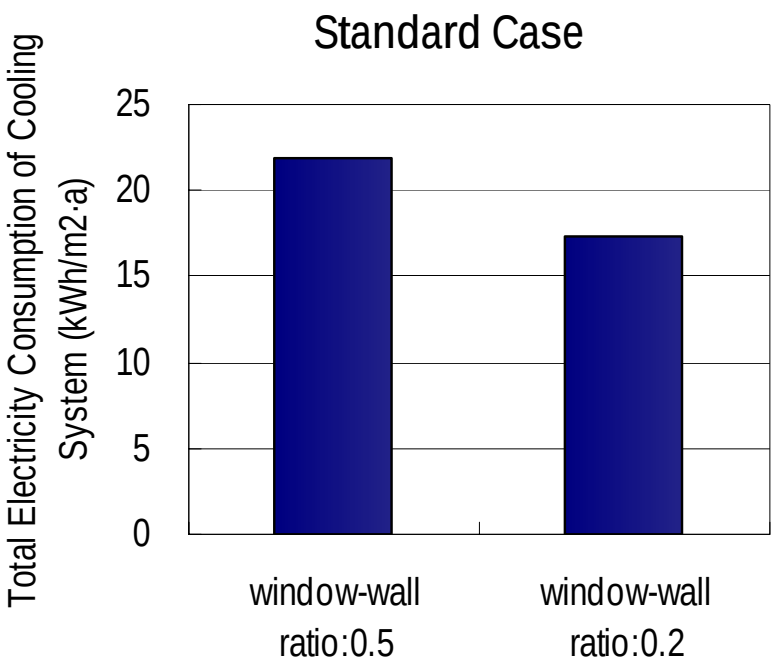
- **Does building operation manner heavy effect on building energy optimization?**
- **Comparison the standard case and the maximum saving case**
  - **Insulation level**
  - **Window size**
  - **Internal / external insulation**
  - **Effect of shading device**
  - **Centralized or decentralized AC for residential**

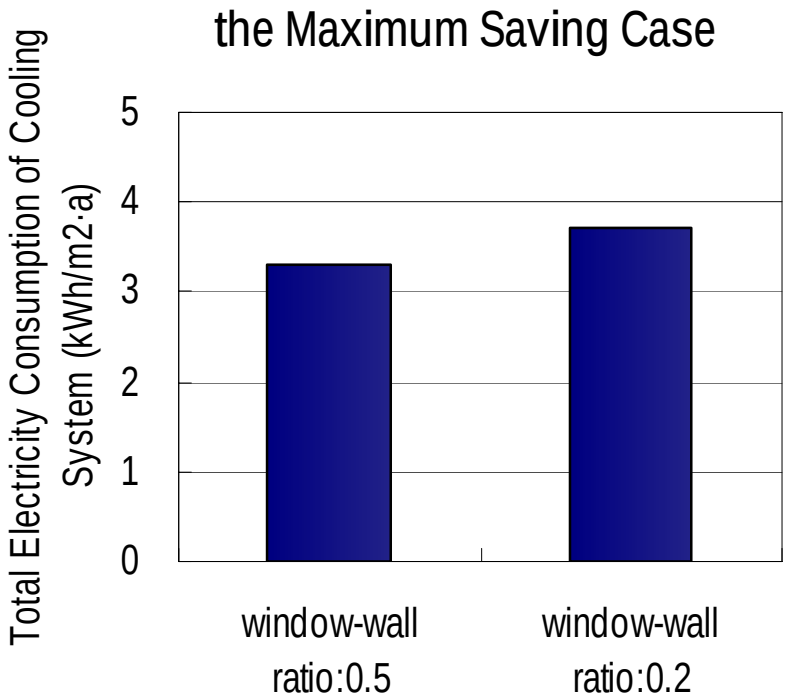
Insulation level required



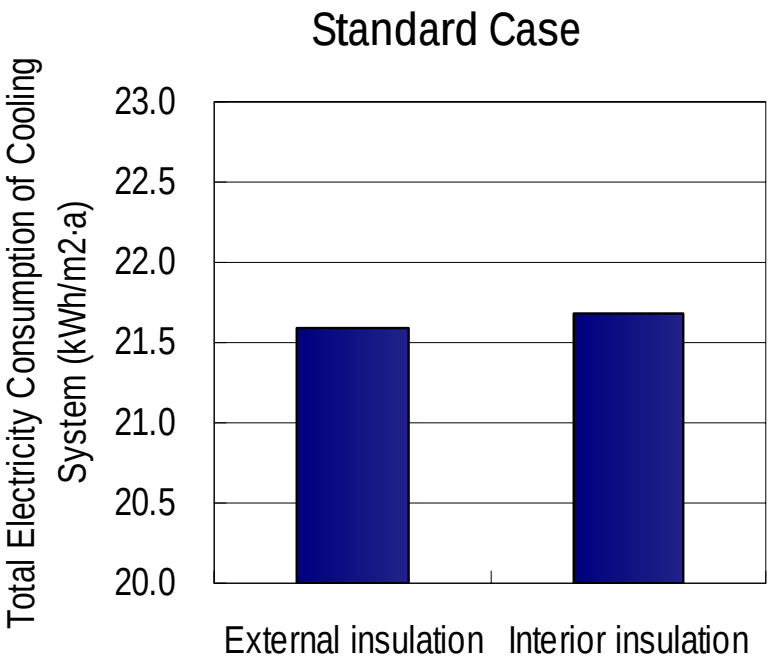


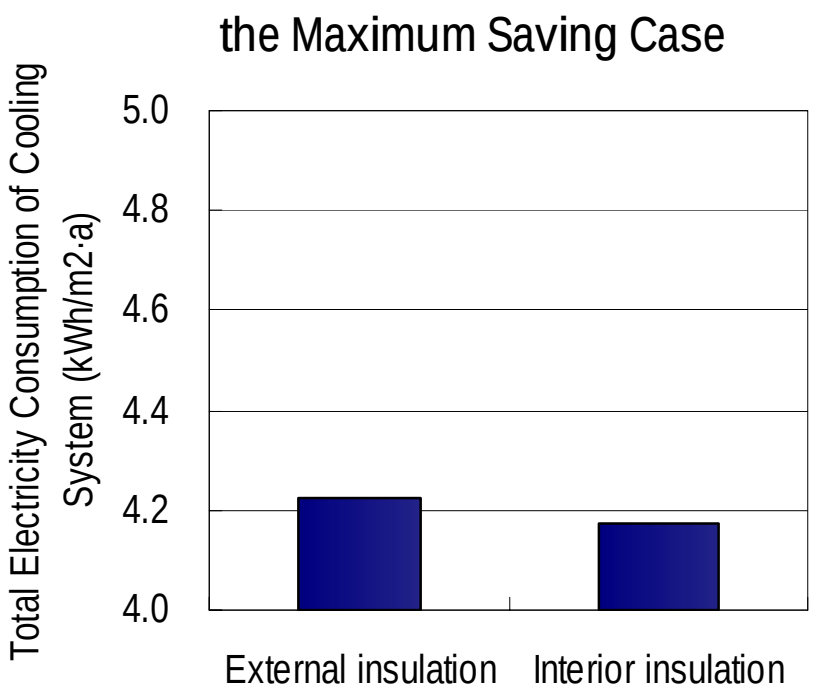
Window size required



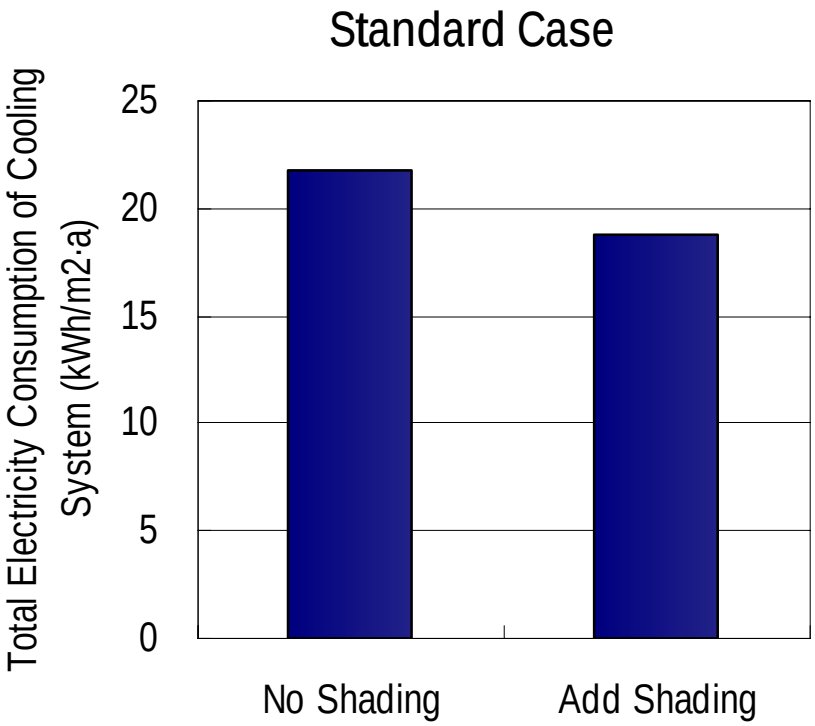


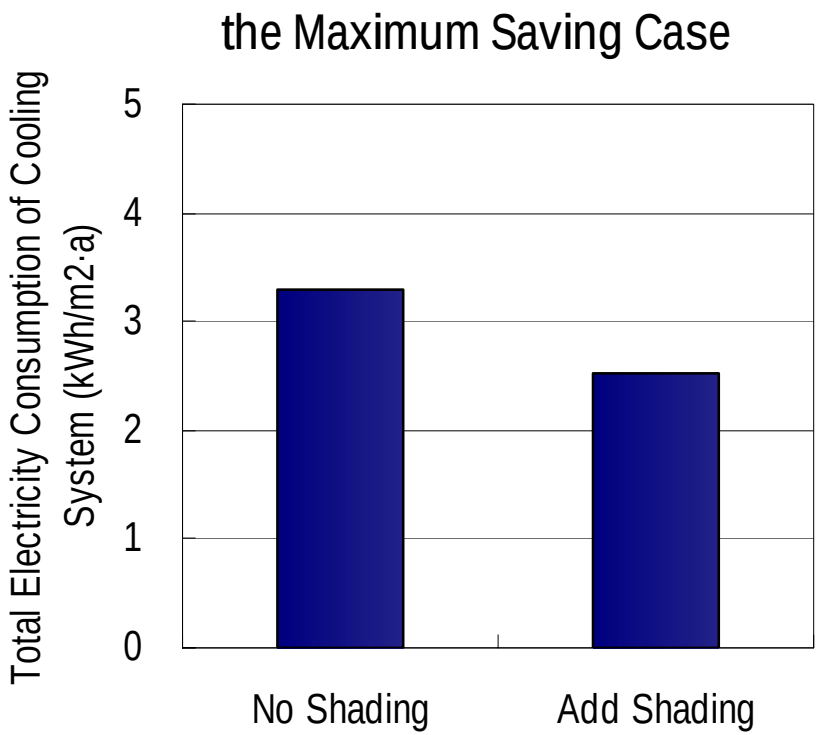
Internal / external insulation





Effect of shading device

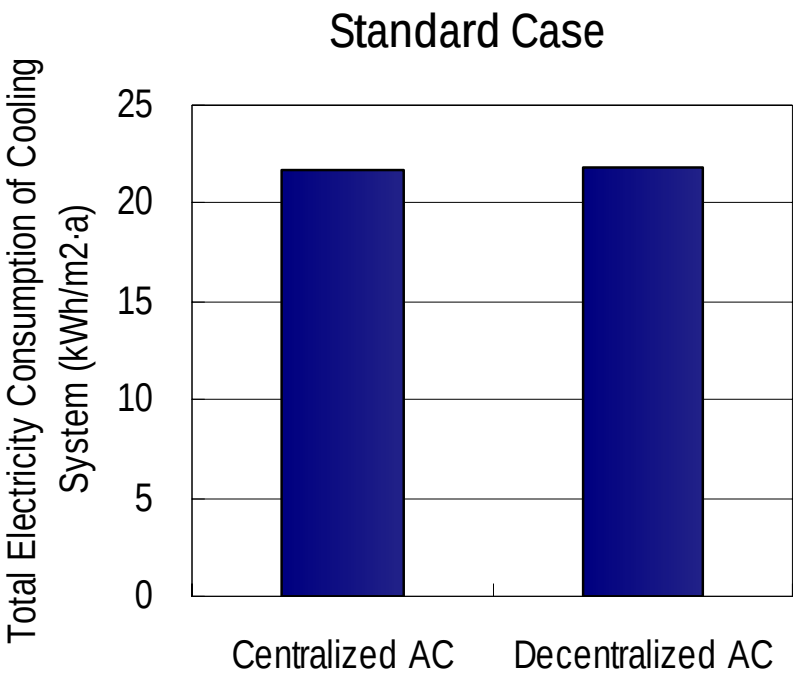


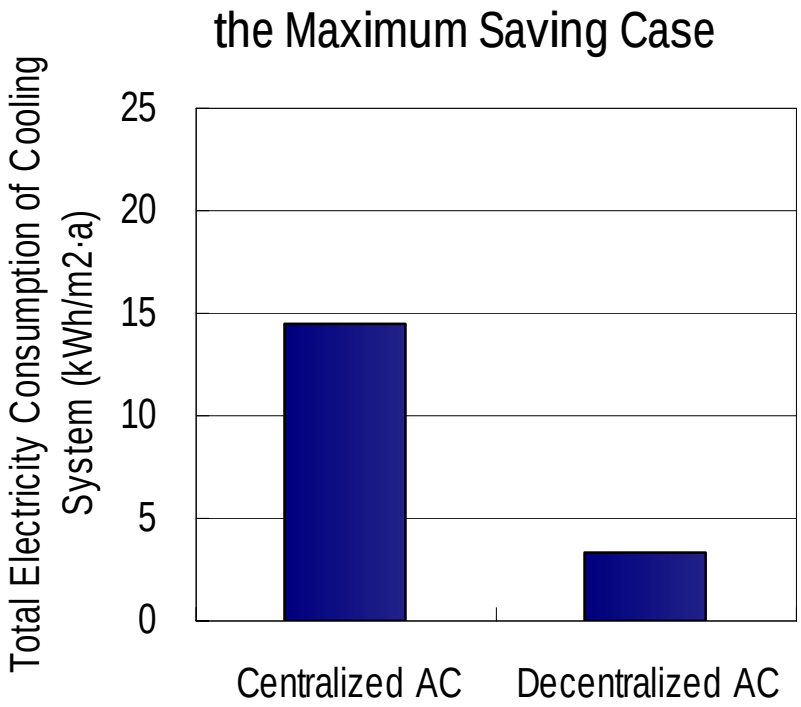


Add shading can reduce 14% of electricity

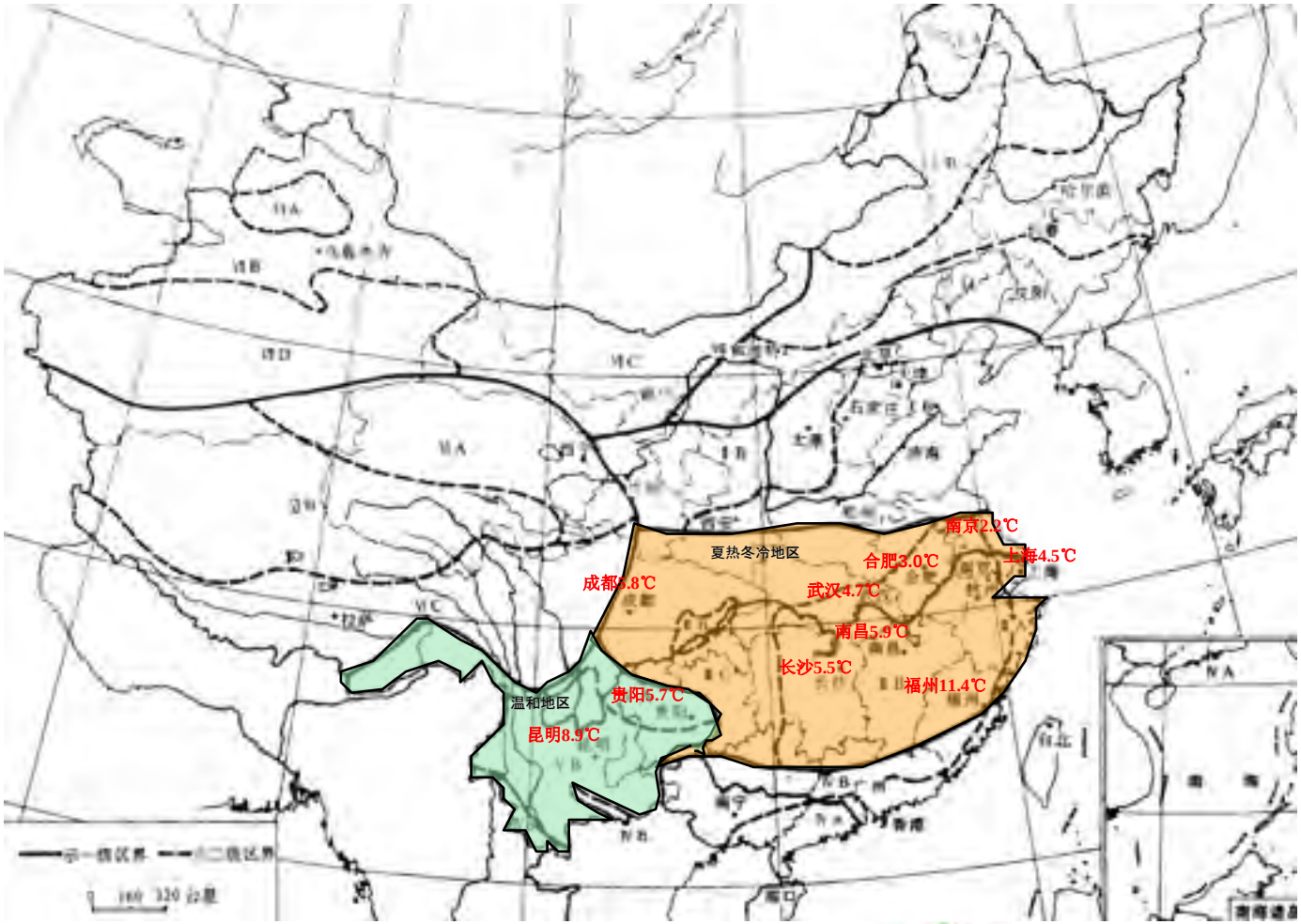
Add shading can reduce 23% of electricity

Centralized or decentralized AC for residential



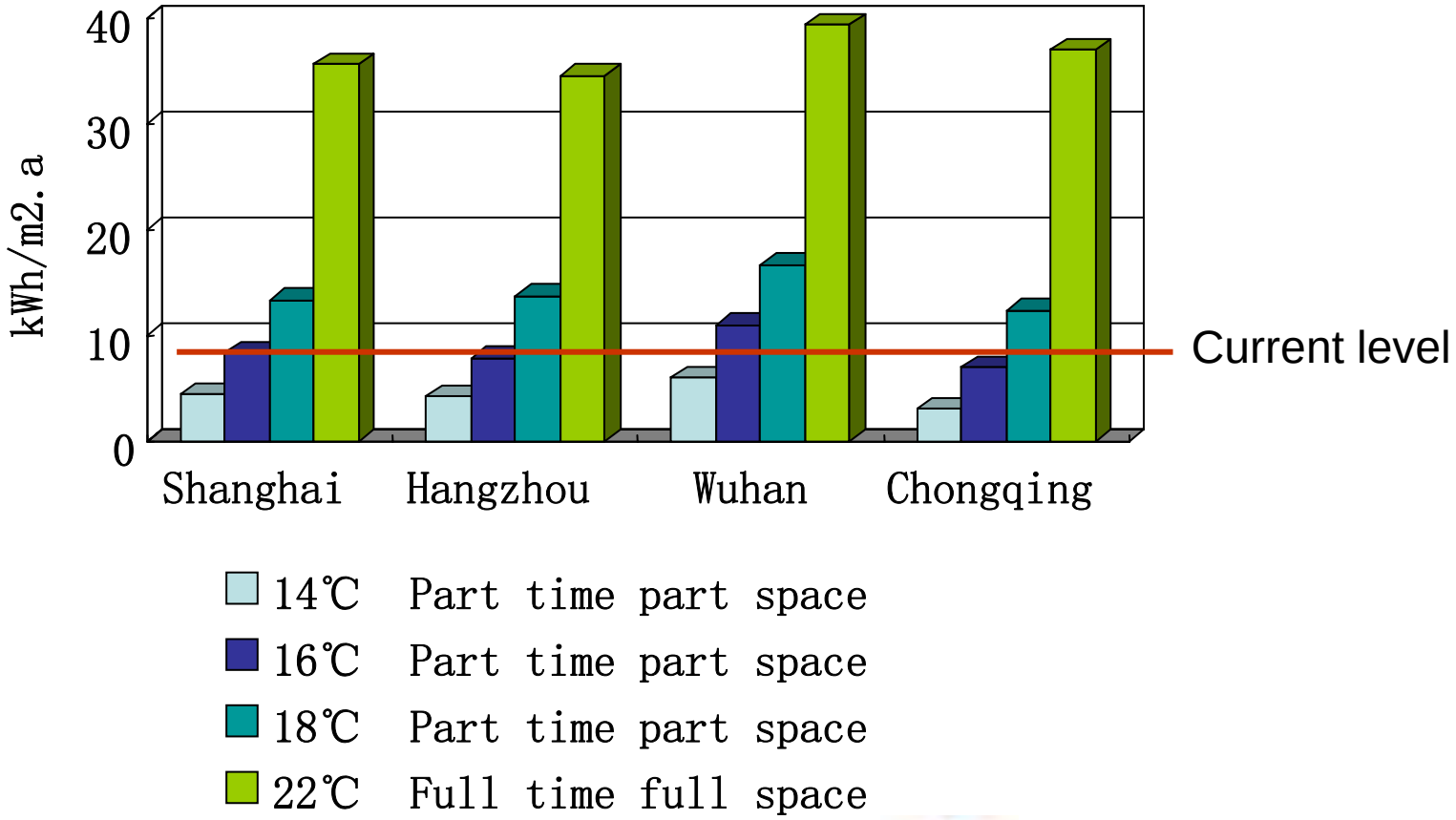


Space heating in southern urban buildings

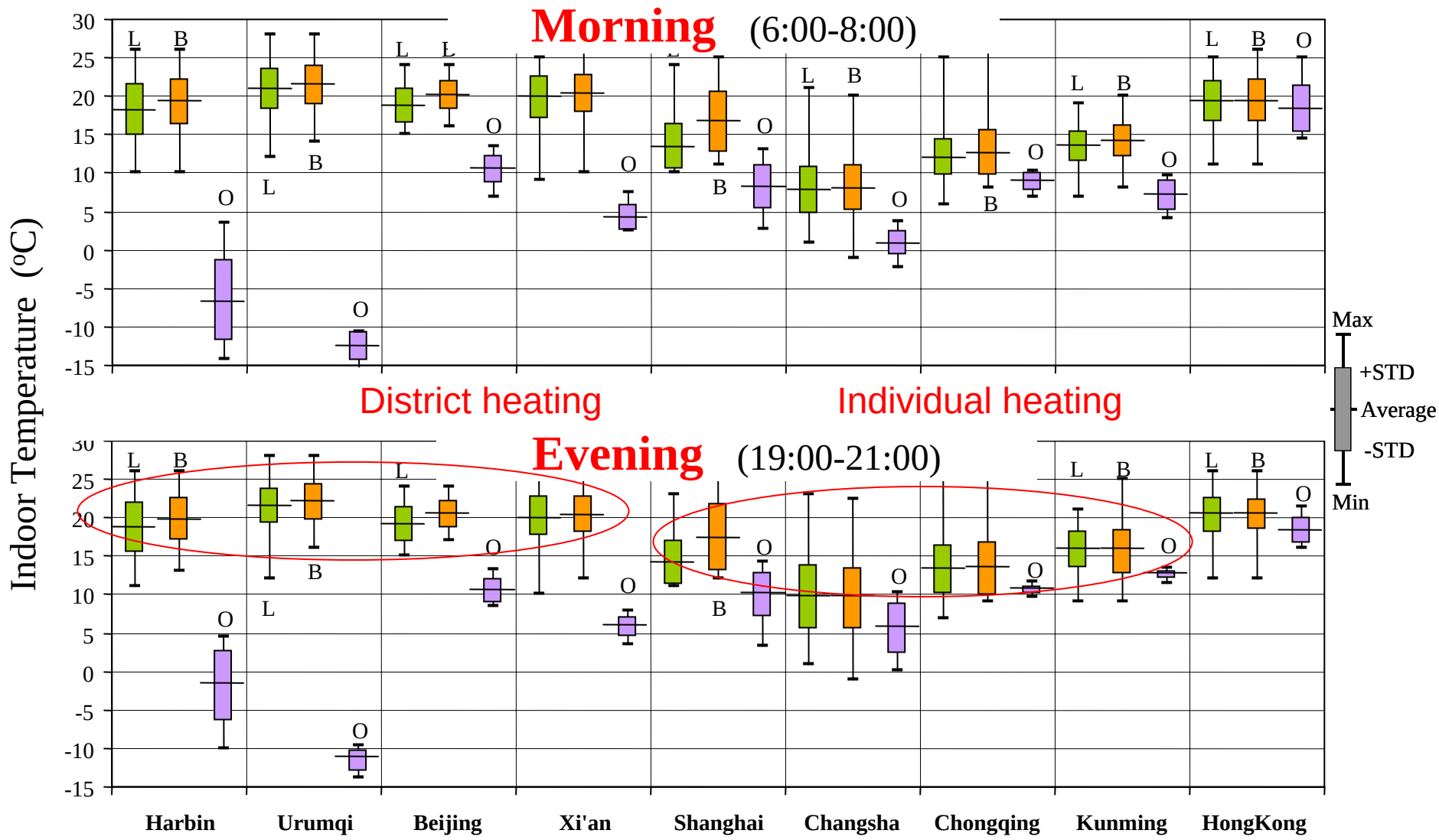


Heating in Yangtze river region, China

Heat pumps, COP=1.9



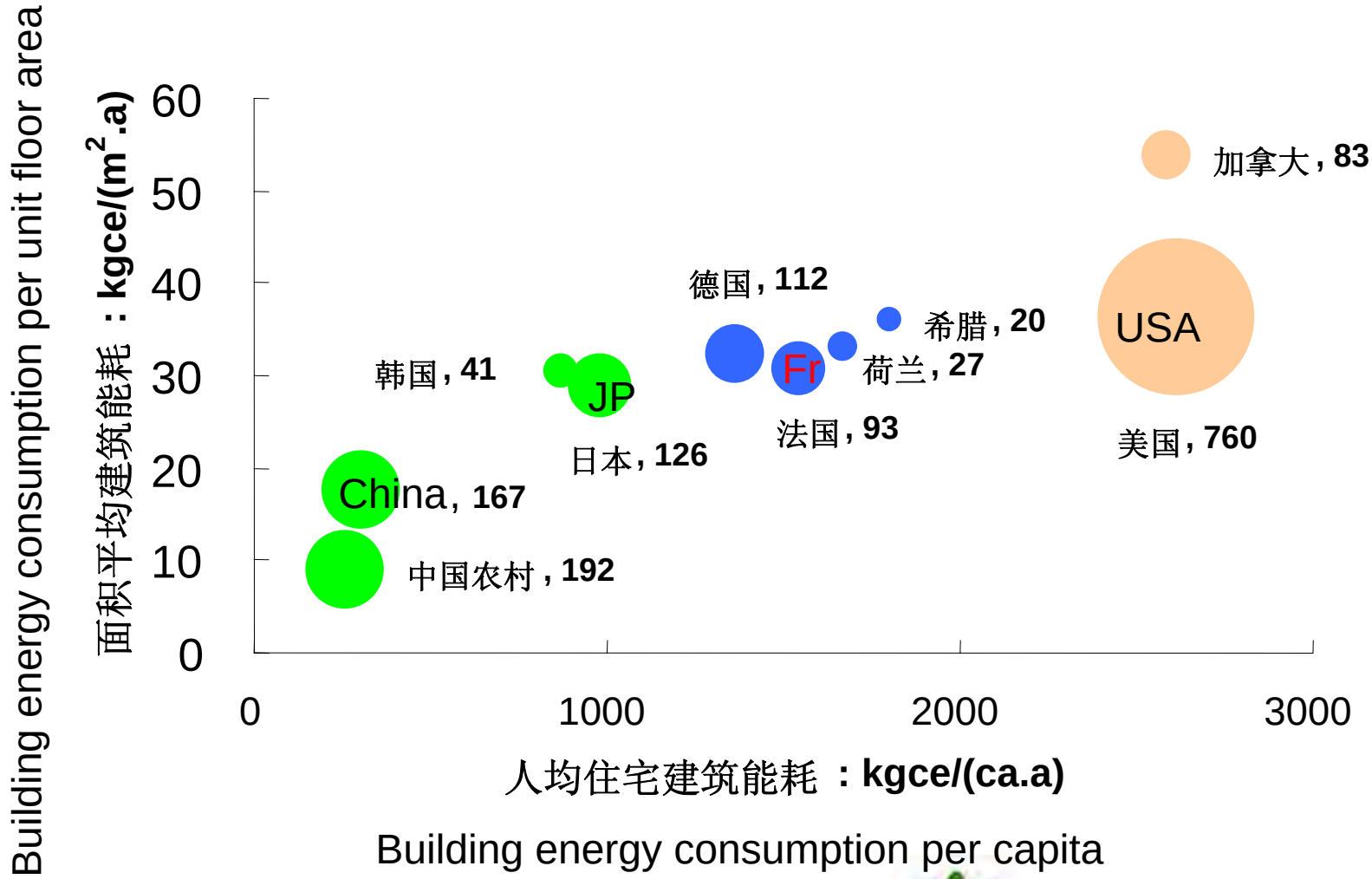
Indoor temperatures in winter



Heating in Yangtze river region, China

- **Low indoor temperature (14℃～16℃） & part time part space heating is the main reason of the low energy use in heating in this area**
- **With current decentralized system & market driven, most people run their local heating in “part time, part space” way with ~6 kWh/m^{2}a, (~2.5kgcoal/m^2)**
- **When service with district heating system, energy use would jump from 2.5kgCoal/m^2 to 10kgCoal/m^2**
- **Should keep the low energy situation or force the high quality service & high energy use by installation of district heating system?**

Energy for residential exclude heating



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What we learnt from EC in residential?

- Current EC of residential building in China is much lower than OECD countries
- The reason is due to different ways in use of service systems, with decentralized system and market mechanism
- When go to centralized systems without a effective control & tariff system, energy consumption will go up greatly such as the heating in North urban China
- Some high energy consumption apparatus, such as cloth dryer, not entry Chinese market is also one of the reasons

Case studies: Office buildings

Tsinghua school
4650m^2，34kWh/m^2·a

Tsinghua art school
64k m^2，65.7kWh/m^2·a

Government office A
16k m^2，70.1kWh/m^2·a

Government office B
37k m^2，113kWh/m^2·a

Towel in Shanghai
287k m^2，215kWh/m^2·a

Office building A, USA
6425m^2，364kWh/m^2·a

Office building B, USA
30k m^2，356kWh/m^2·a

Office building, Lyon
17k m^2，165kWh/m^2·a

Energy consumption items

TH1

TH2

BJ1

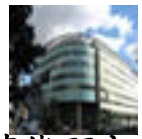
BJ2

BJ3

SH1

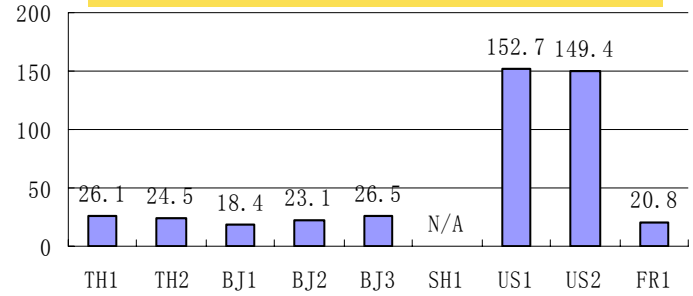
US1

US2

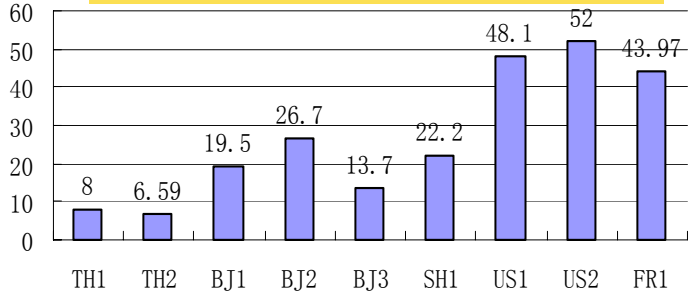


FR1

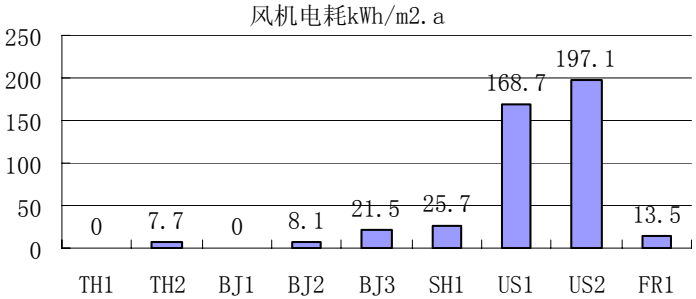
Lighting & appliances (kWh/m²·a)



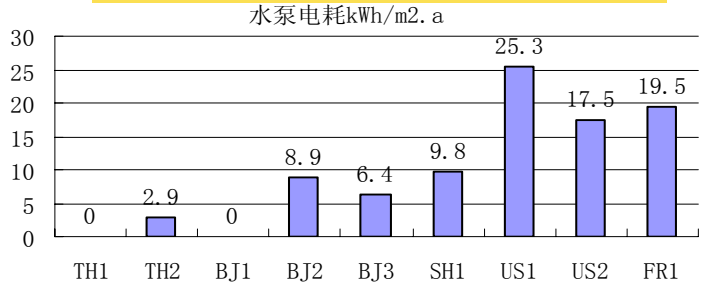
Chiller (kWh/m²·a)



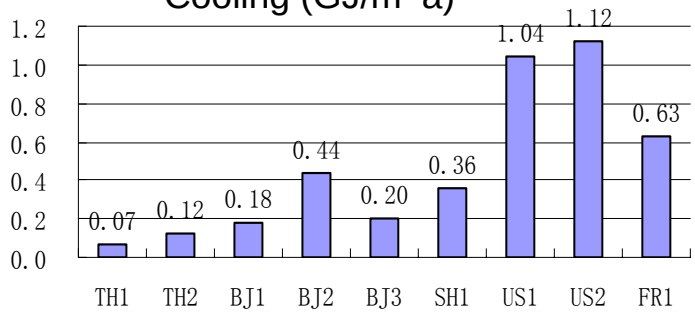
Fan for AC system (kWh/m²·a)



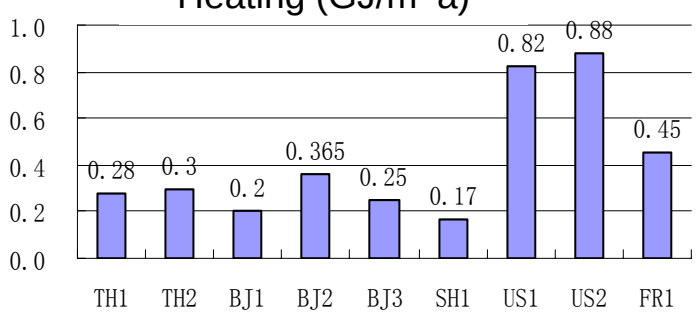
Pump for AC system (kWh/m²·a)



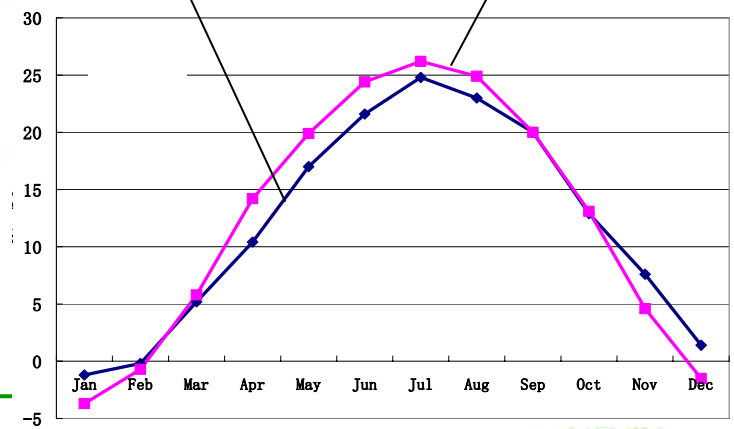
Cooling (GJ/m²·a)

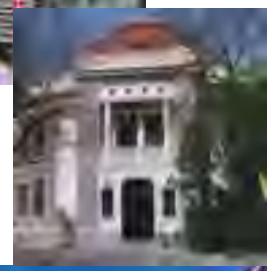


Heating (GJ/m²·a)

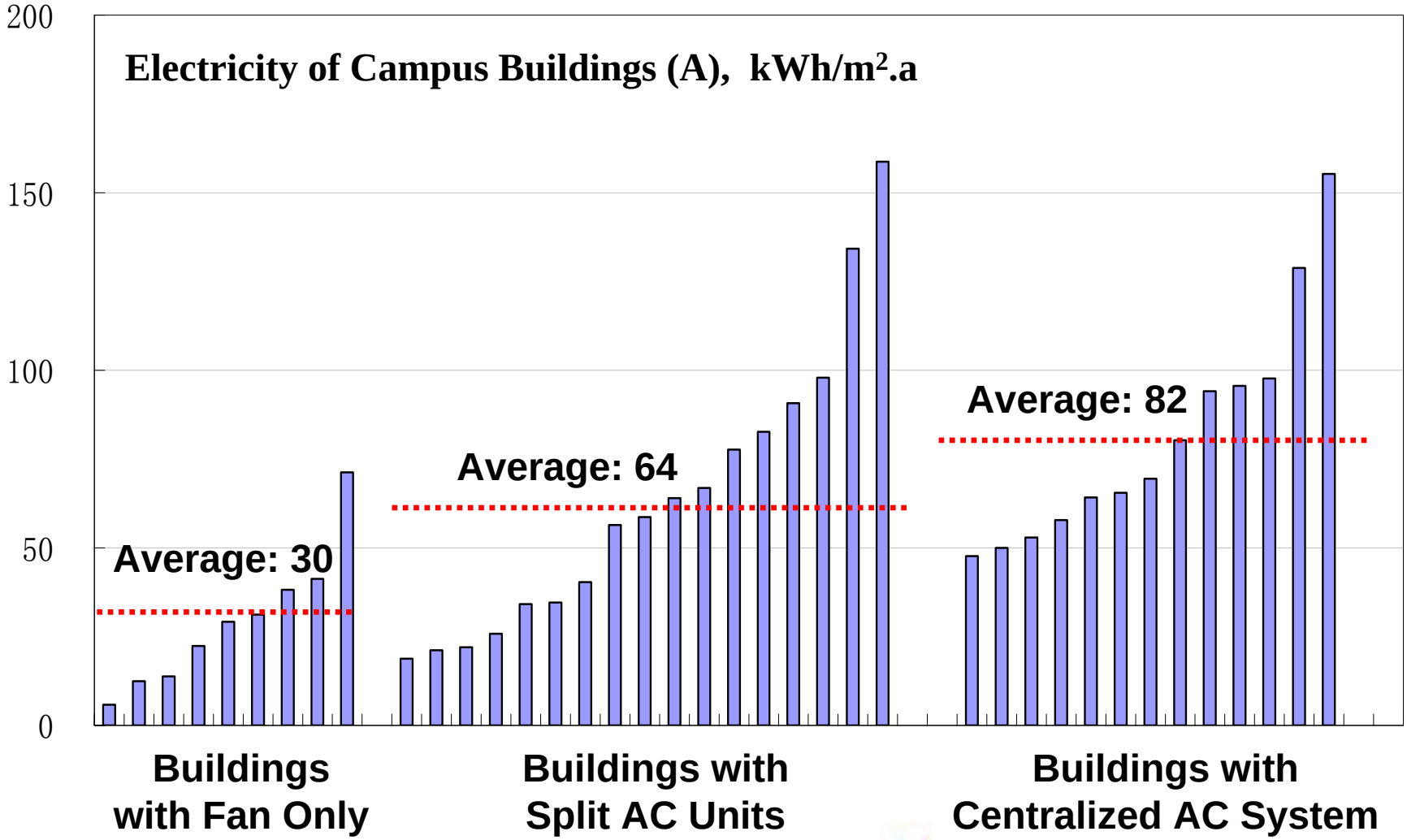


Case study： BE in campus buildings





Observations on a Campus in Beijing



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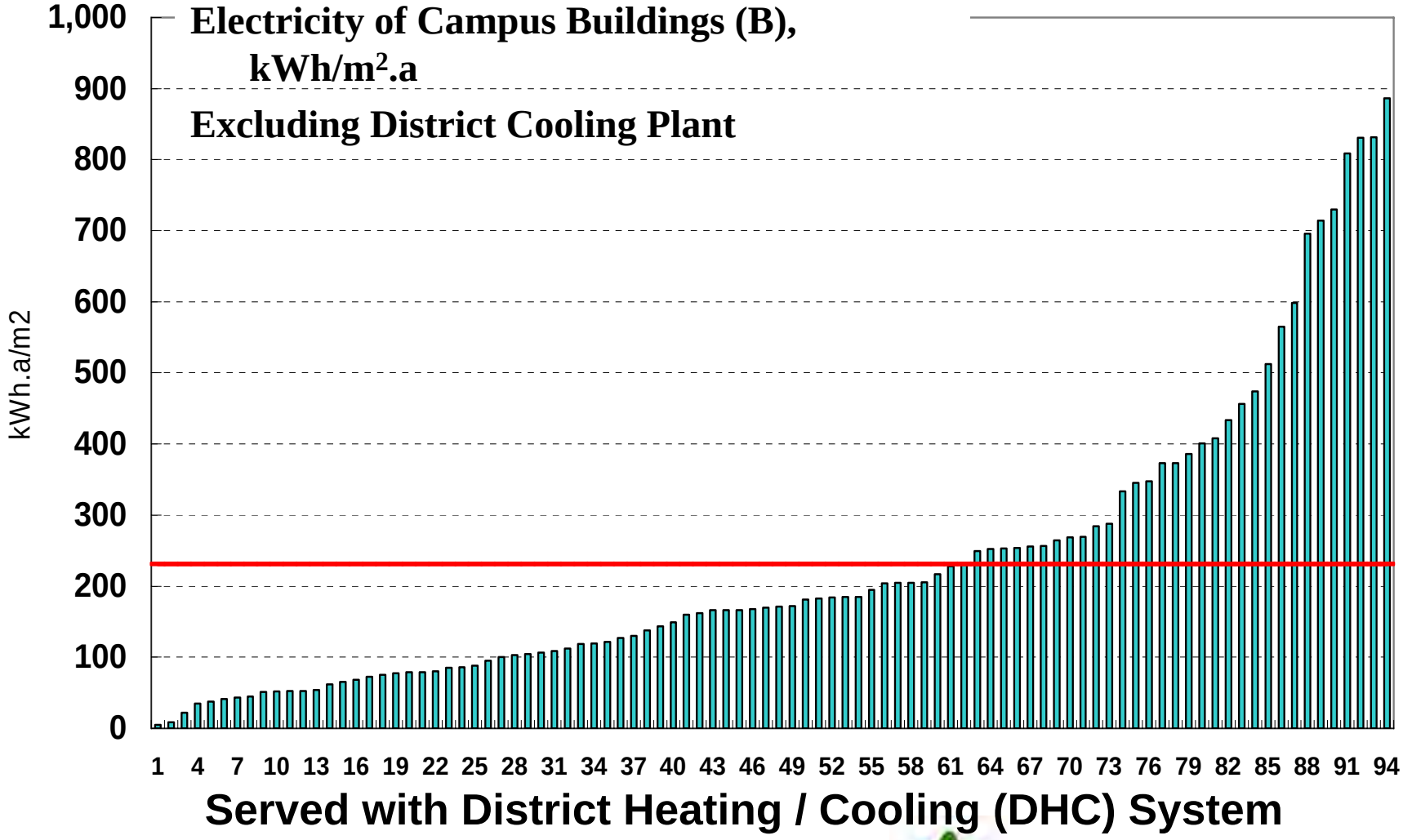
Observations in Campus in Philadelphia



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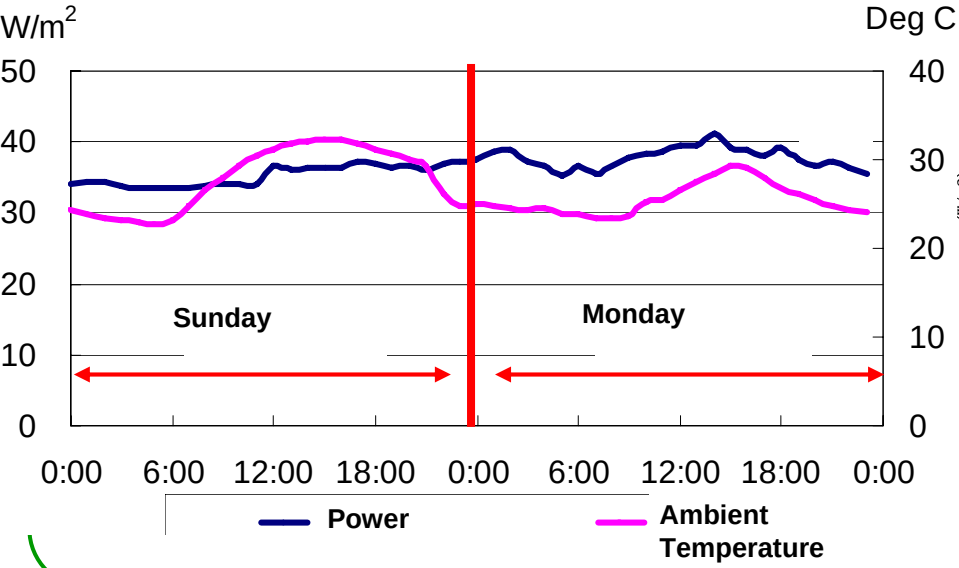
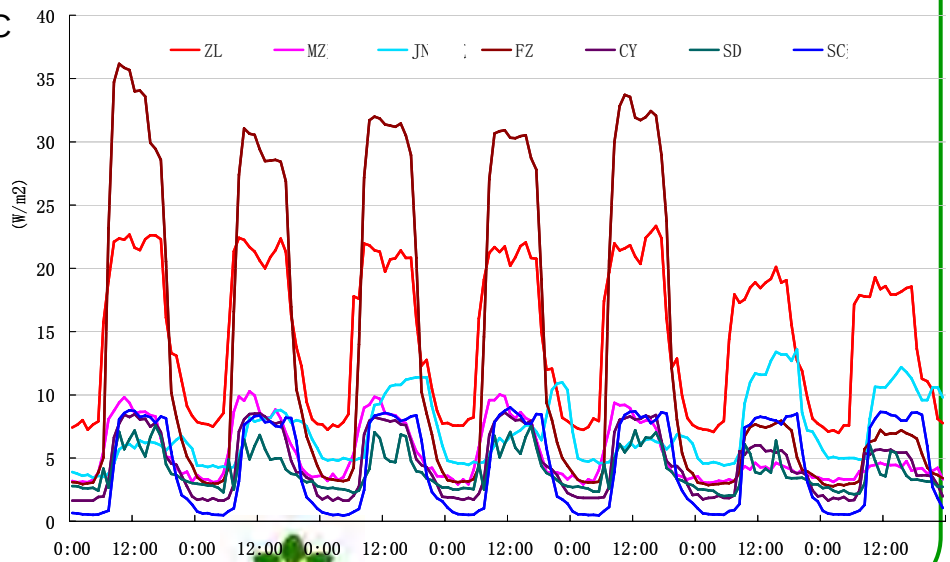
Reasons of the differences in energy

- **Energy by fans for ventilation**
  - **Air sealed buildings: 70 ~ 110 kWh/m^2.a**
  - **Full air system: 30 ~ 70 kWh/m^2.a**
  - **Natural ventilated: < 10 kWh/m^2.a**
- **Operation hours**
- **Way of operations, re-heat, etc.**





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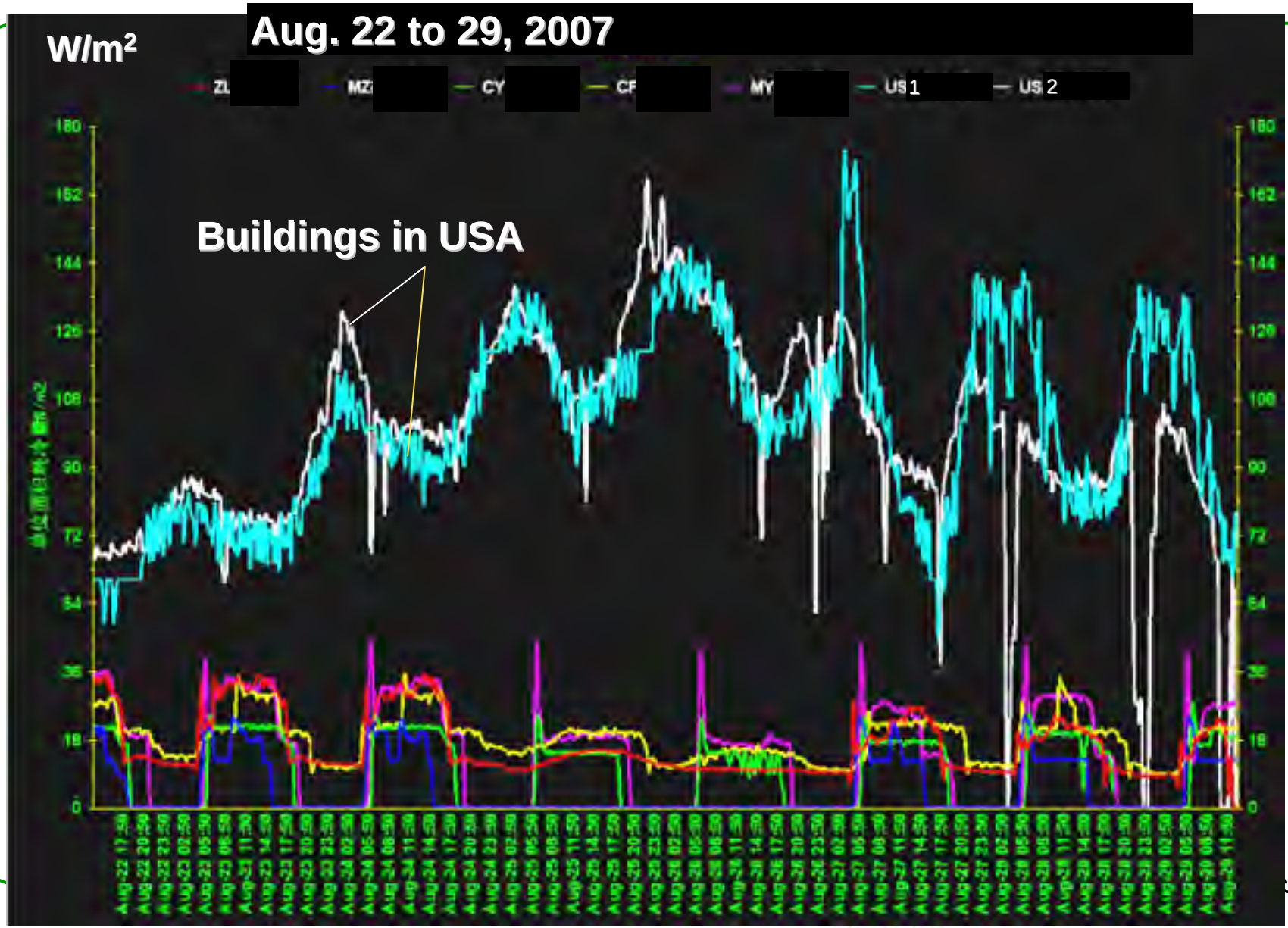
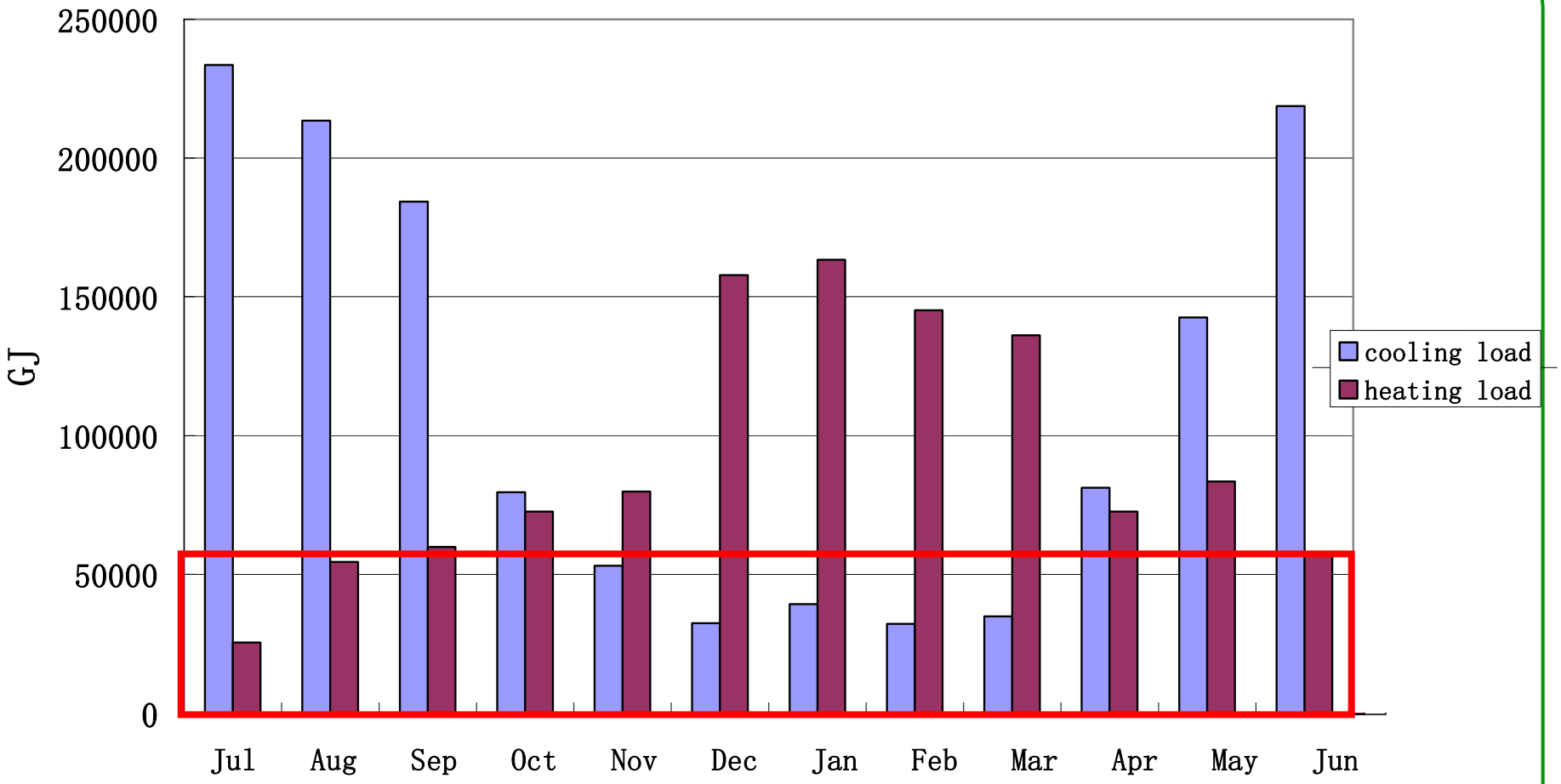
Cooling consumed during summer



Heating & cooling for an USA campus

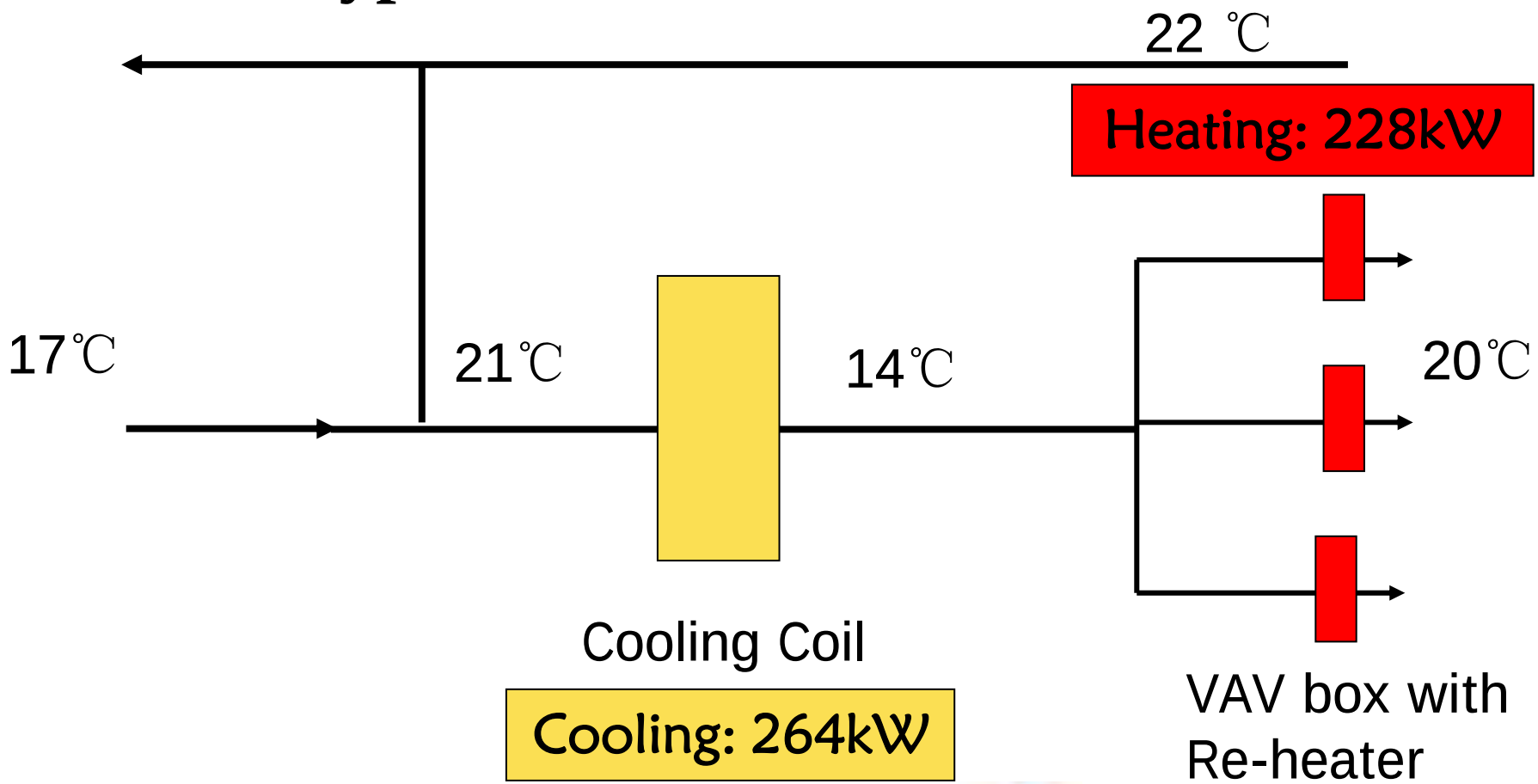
- **Cooling, 2005-2006**
  - **1,344,744 GJ**
  - **1.02GJ/m^2**
- **Heating, 2005-1006**
  - **1,108,598 GJ**
  - **0.84GJ/m^2**
- **Office buildings in other countries (GJ/m^2)**
  - **Beijing: 0.25~0.35**
  - **Tokyo: 0.43**
  - **Shanghai: 0.36**
- **Office building in other countries (GJ/m^2)**
  - **Beijing: 0.15~0.35**
  - **Tokyo: 0.45**
  - **Germany: 0.4**

Heating & cooling in an USA campus



Re-heat cost the most cooling & heating

- **AHU, typical state in October**



Main reasons for the difference in EC

- Continue operation / part time operation for AC & lighting: ~ 2 times in total energy
- Mechanical ventilation / natural ventilation: more than 100 kWh/m^2 / less than 10 kWh/m^2
- Different set point for temperature: 50% in cooling demand
- VAV system / FCU or split unit
- With / without re-heat: 2 times in heating & cooling demand

Reference value for Beijing non-residential

Function	Normal ($kWh/m^2.a$)	High standard ($kWh/m^2.a$)
Office	30~50	90~160
Shop	~ 50	200~350
Hotel	~70	100~180
Classroom	15~45	65 ~ 100

Major differences between high standard & normal:

- Size and shape, natural lighting or artificial lighting
- Window opening, natural ventilation or mechanical vent.
- Air-conditioning, VAV, FCU or fully decentralized
- Envelope: glassing or normal

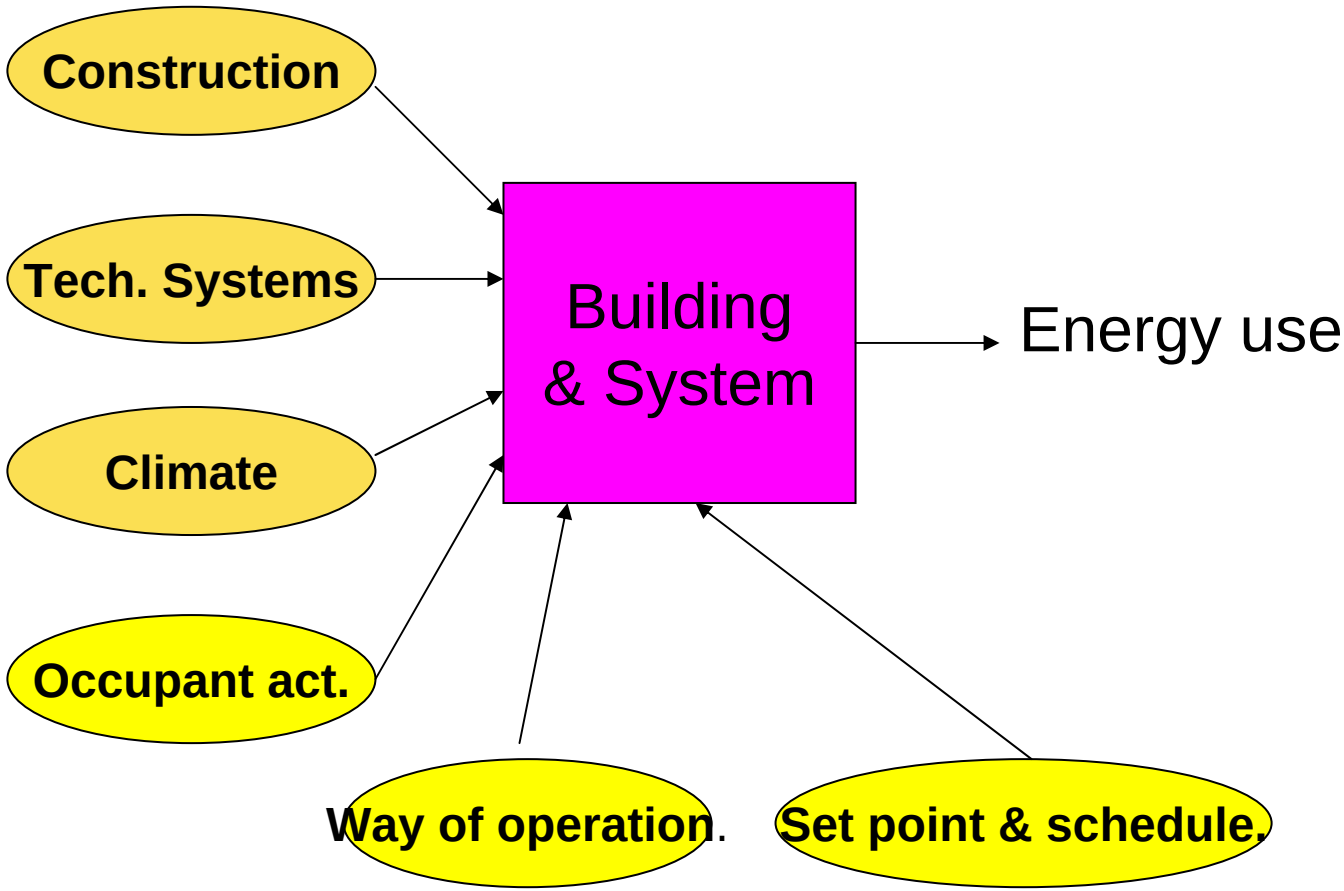
Two approaches for built environment

- **Mechanical first**
  - **Total control**
  - **Constant**
- **Build**
  - **As**
  - **As**
  - **Me**
    hea
  - **Cer**
- **Operation**
  - **Full time & full space**

- **Natural first**
  - **Connect with natural**
  - **Improve by mechanical**
    ate
    yle
- **Operation**
  - **Part time & part space**

- Main reason for the huge difference in energy consumption between developed & developing countries
- There is some kinds of difference in service level provided
- Should the East keep this cultural & lifestyle rather than go to the West?
- It is the big challenge & the key issue for sustainable develop

Factors influence building energy use



What does mean lifestyle here?

- **Demand of indoor environment**
  - Temperature & humidity: constant / variety
  - Outdoor air: constant / variety
  - Service operation: full time / in schedule
- **Adjust building fabric to coordinate with climate**
  - Window opening for ventilation
  - Shading adjusting for lighting & thermal
- **Service system**
  - Full space / part space;
  - Uniform / individual
  - Centralized / decentralized

These should all be clearly defined and modeled in order to study lifestyle related building energy performance

Possible solution: green lifestyle

- Combination of technique innovation & green lifestyle
- What should be the “design criteria” ?
  - In building energy prediction & performance evaluation
  - In building & service system design
- Green lifestyle cannot happen with “standard” building & system design
  - Window open able?
  - Service system adjustable individually?

Different approaches to reach comfort

- **What level of insulation should be in Hong Kong or Guangzhou?**
  - **If indoor temperature required is 22 ℃～24℃, heavy insulation and airtight is recommended**
  - **If indoor temperature required 16℃～29℃, light insulation, adjustable external shading & high rate natural ventilation are most important, heavy insulation will increase cooling demand**
- **What kind of building should be built? What should be in the building energy code?**

Different approaches to reach comfort

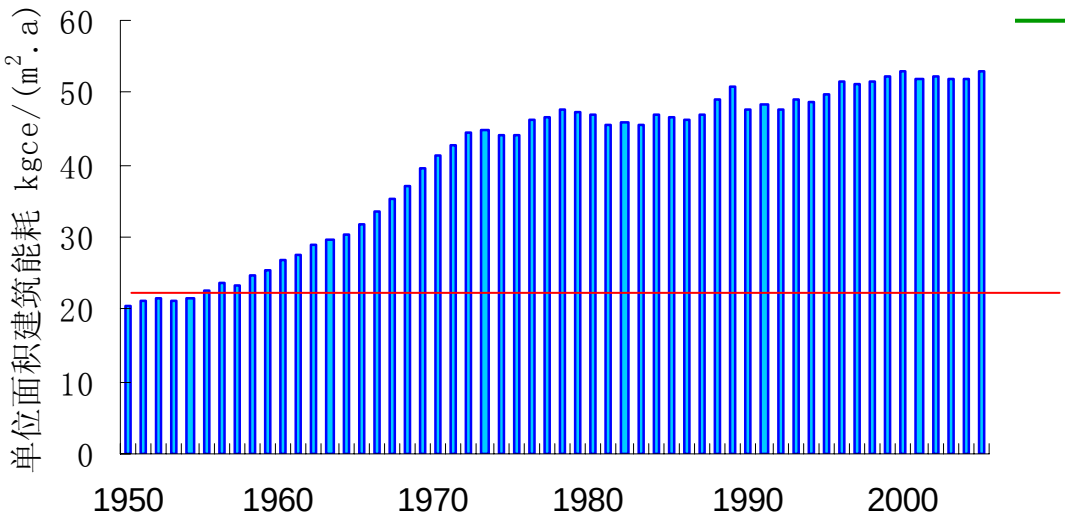
- **Ventilation with a heat recover unit, fully closed windows**
  - Constant outdoor air volume
  - Inlet air state is always near indoor state due to high efficiency heat recover
  - 5 W/m^2 for fan, that is 44 kWh/m^{2}a
  - 80 kWh/m^2.a cooling to exhaust heat, or 30 kWh/m^2.a electricity
  - 44+30=74kWh/m^2.a electricity

- **Open window for natural ventilation if outside is fair, close window during extreme hot & cold**
  - No fan energy
  - 40 kWh/m^2.a cooling to exhaust heat, or 15 kWh/m^2.a electricity
  - 20~30 kWh/m^2.a more heat for heating up outdoor air or 15 kWh/m^2.a electricity if heat is provided by heat pump
  - 15+15=30kWh/m^2.a electricity

Different approaches to reach comfort

- **Centralized air-conditioning for multi-family residential buildings or decentralized?**
  - **If all 24 hours service with equal indoor climate, centralized system may save energy by high efficiency**
  - **If only part time part space service required, decentralized may only consume 10%~20% energy comparing with centralized**
- **Why we do large district cooling system?**
  - **Efficiency of centre plant may increase ~10%**
  - **Large pump power consumed through piping network**
  - **Suitable for equal cooled buildings, not suitable for "part time, part space" cooling demand**

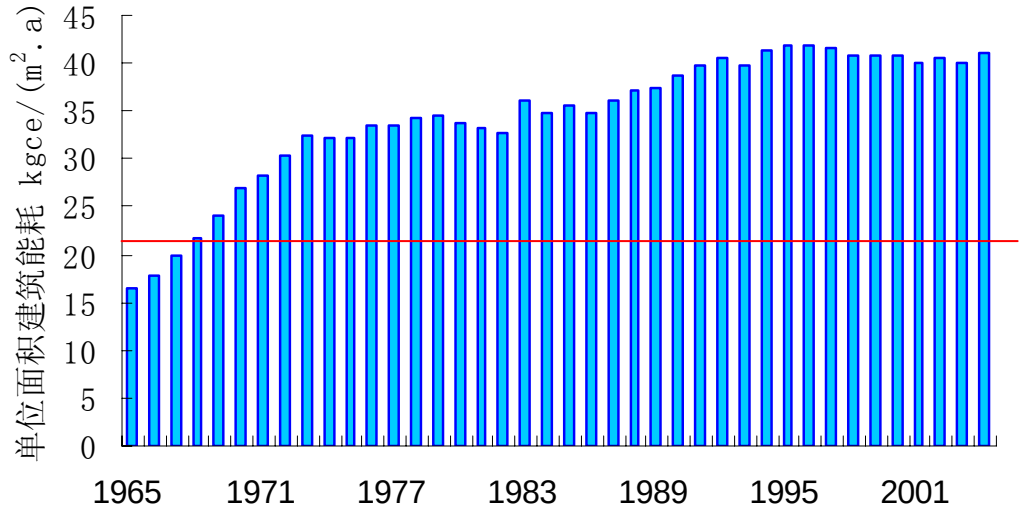
History and trend: energy in buildings



China current level

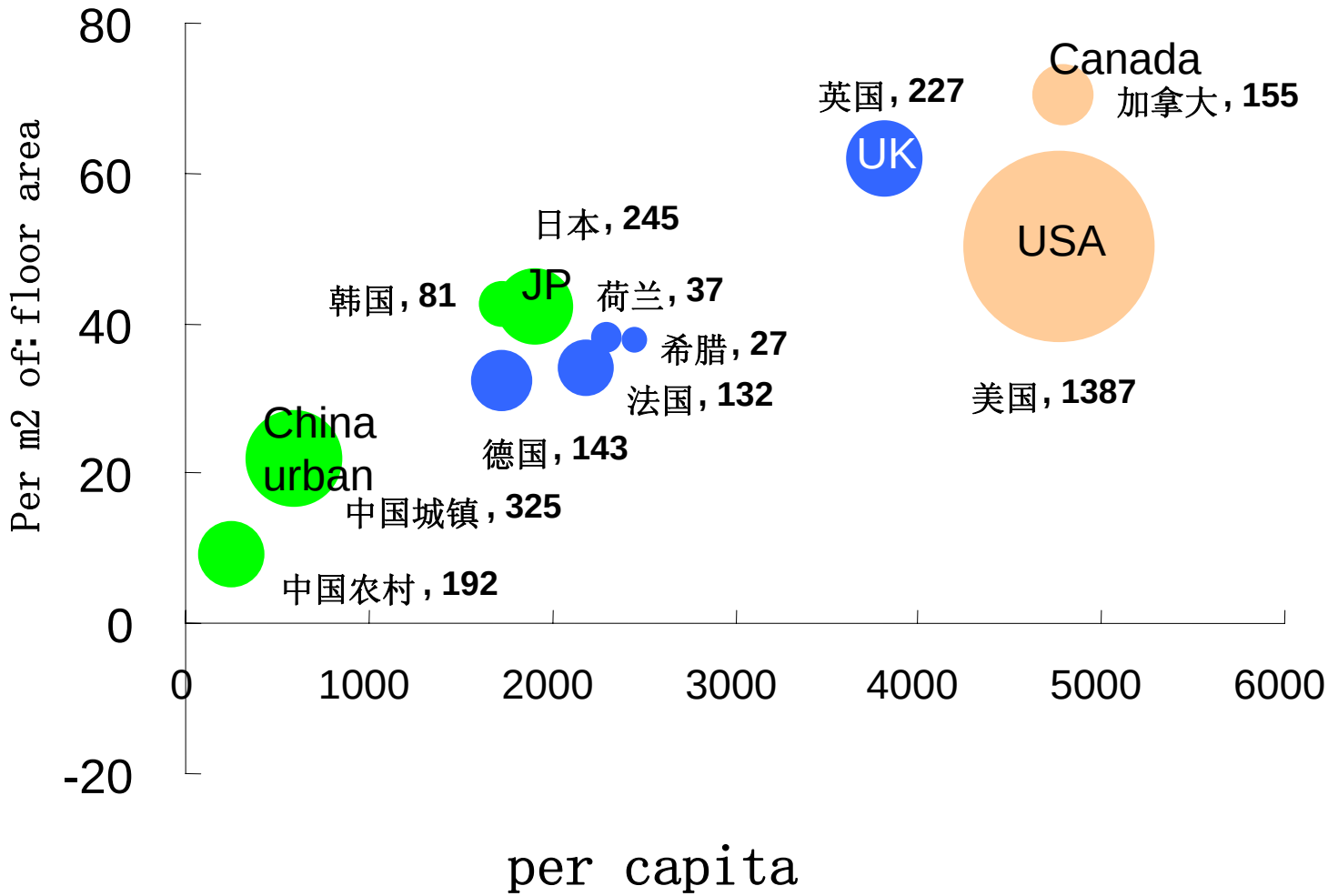
Japan: kgce/m2.a

USA: kgce/m2.a

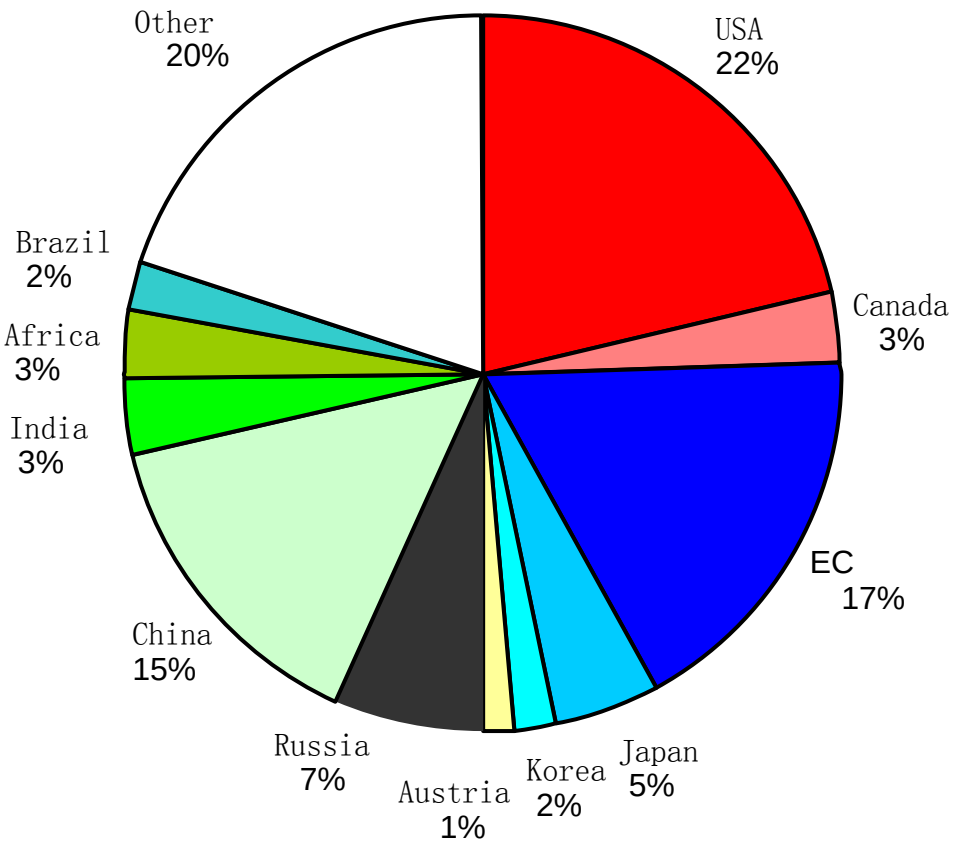


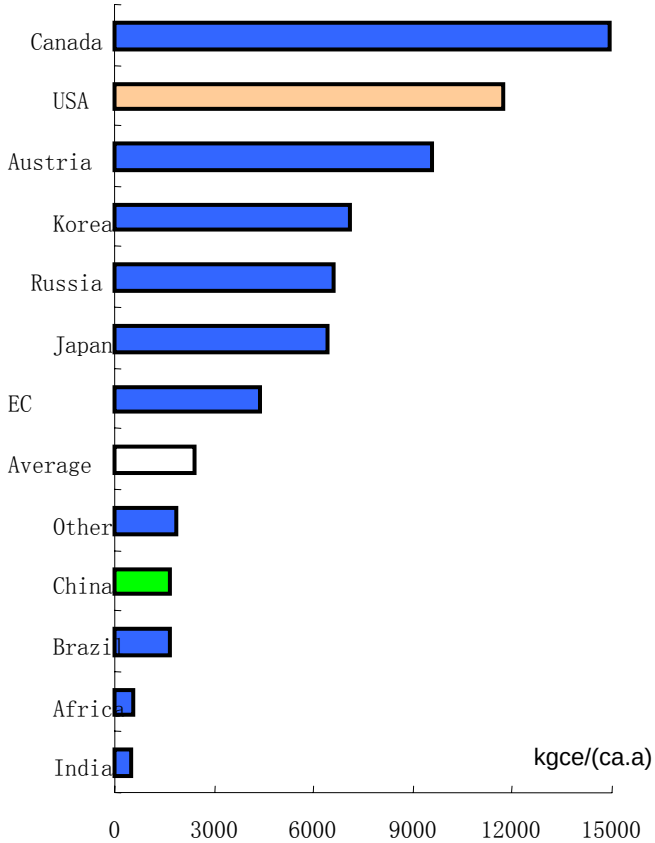
Where the new economic group countries such as India, Brazil, and China, with 3 billion populations will go?

Current building energy use (kg coal/a)



Energy consumption in the world (2005)

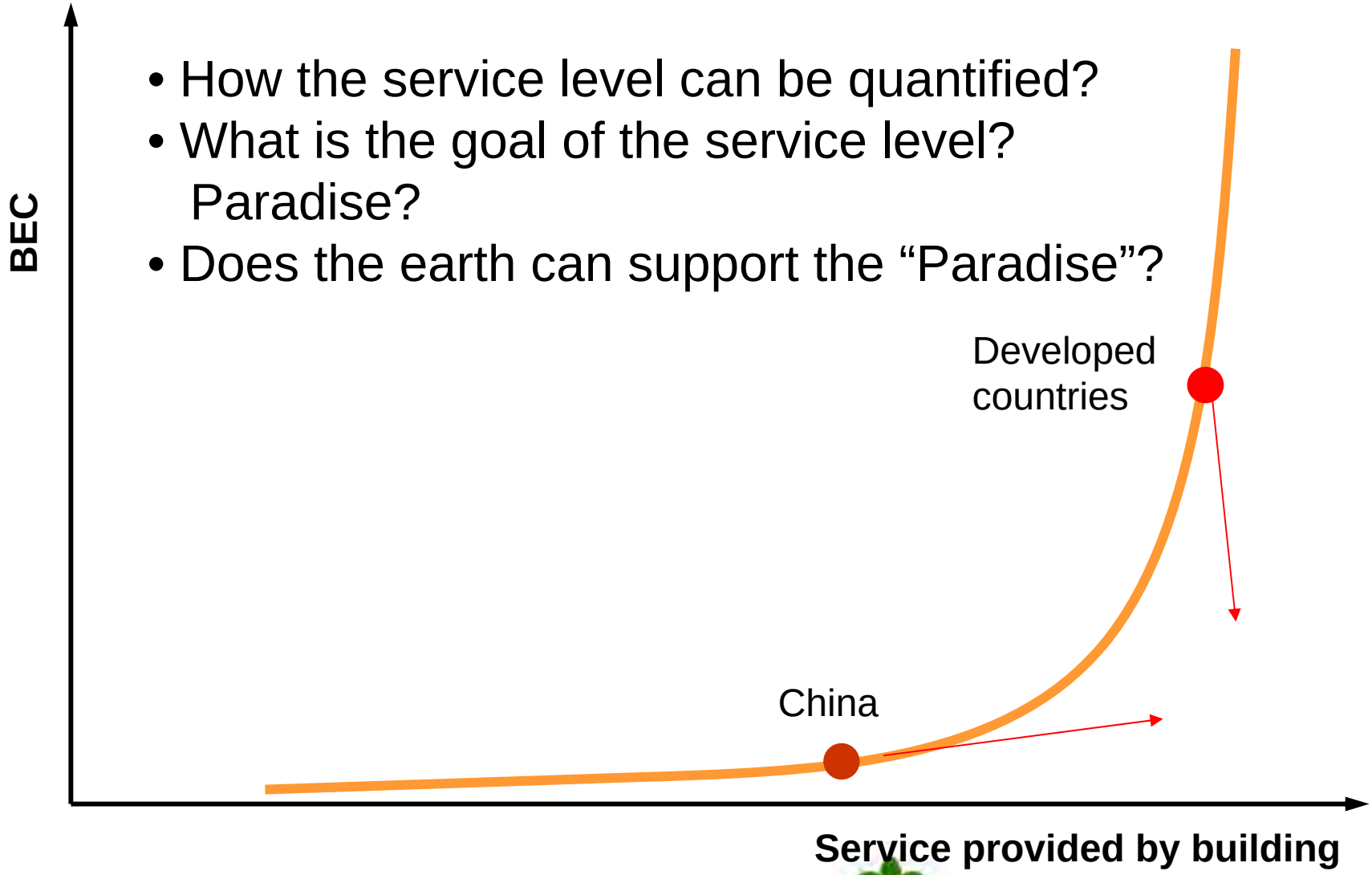




Data source: Energy Information Administration. International Energy Outlook 2008.

Relationship between BEC and service

- How the service level can be quantified?
- What is the goal of the service level?
  Paradise?
- Does the earth can support the “Paradise”?



Conclusion

- Huge difference in building energy consumption between OECD & developing countries such as China
- The difference is not due to the techniques, but due to lifestyle & culture
- It is important to study how building energy related with lifestyle
- Future solution for developing countries should be the encouragement of green lifestyle and technique innovations based on green lifestyle
- New criteria for building & system design and for energy performance evaluation based on “green life style” should be further studied and developed

Thank you & questions