Building Energy and Passive Design Research in China

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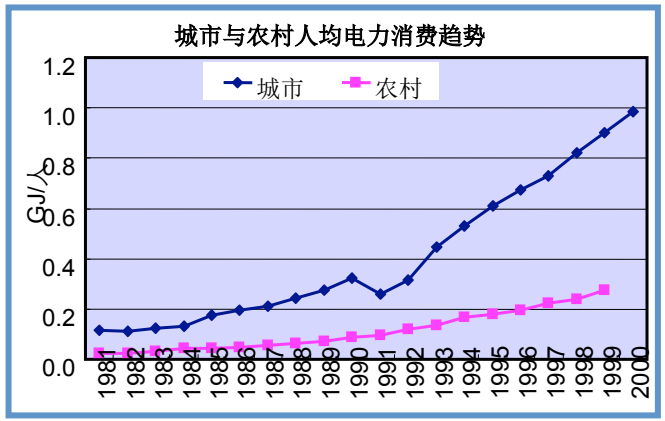
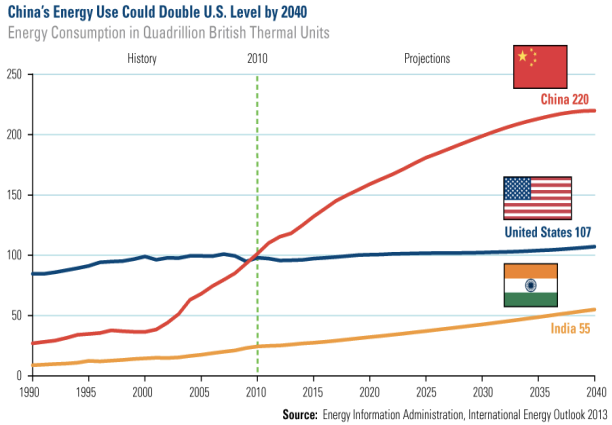
- Background
- Fundamental research
  - thermal comfort
  - climate
- Applied research
  - Passive designs

S1: China urbanization –Gains and Pains





- China has seen rapid urbanization growth in the past 30 years:
  - 1）gains: economic growth, infrastructure (highway, education, hospital etc,);
  - 2） pains: environmental (water and air pollution, high energy demand, green gas emission); historical and cultural (internationalism buildings and cities); social (cities vs rural areas, inequity)
  - Energy efficiency in China is vital not only to China, but also to the whole world.

S2: A brief history of Chinese building energy efficiency standards

- China government has made great efforts..
- 1986 – the first Chinese building energy efficiency standard.
- The standard helped reducing heating energy and improving indoor thermal environment in northern China.

S2: Time line of other major standards/milestones.

Year	Number	Standard Name	Climate Zone	Type	Target
1986	JGJ26—1986	Energy Conservation Design Standard for New Heating Residential Buildings	Severe cold / cold	Residential	30%
1995	JGJ26—1995	Energy Conservation Design Standard for New Heating Residential Buildings	Severe cold / cold	Residential	50%
2001	JGJ134—2001	Design standard for energy efficiency of residential buildings in hot summer and cold winter zone	Hot summer& cold winter	Residential	50%
2003	JGJ75—2003	Design standard for energy efficiency of residential buildings in hot summer and warm winter zone	Hot summer& warm winter	Residential	50%
2005	GB50189—2005	Design standard for energy efficiency of public buildings	All	Public	50%
2010	JGJ26—2010	Design standard for energy efficiency of residential buildings in severe cold and cold zones	Severe cold / cold	Residential	65%
2010	JGJ134—2010	Design standard for energy efficiency of residential buildings in hot summer and cold winter zone	Hot summer& cold winter	Residential	50%*

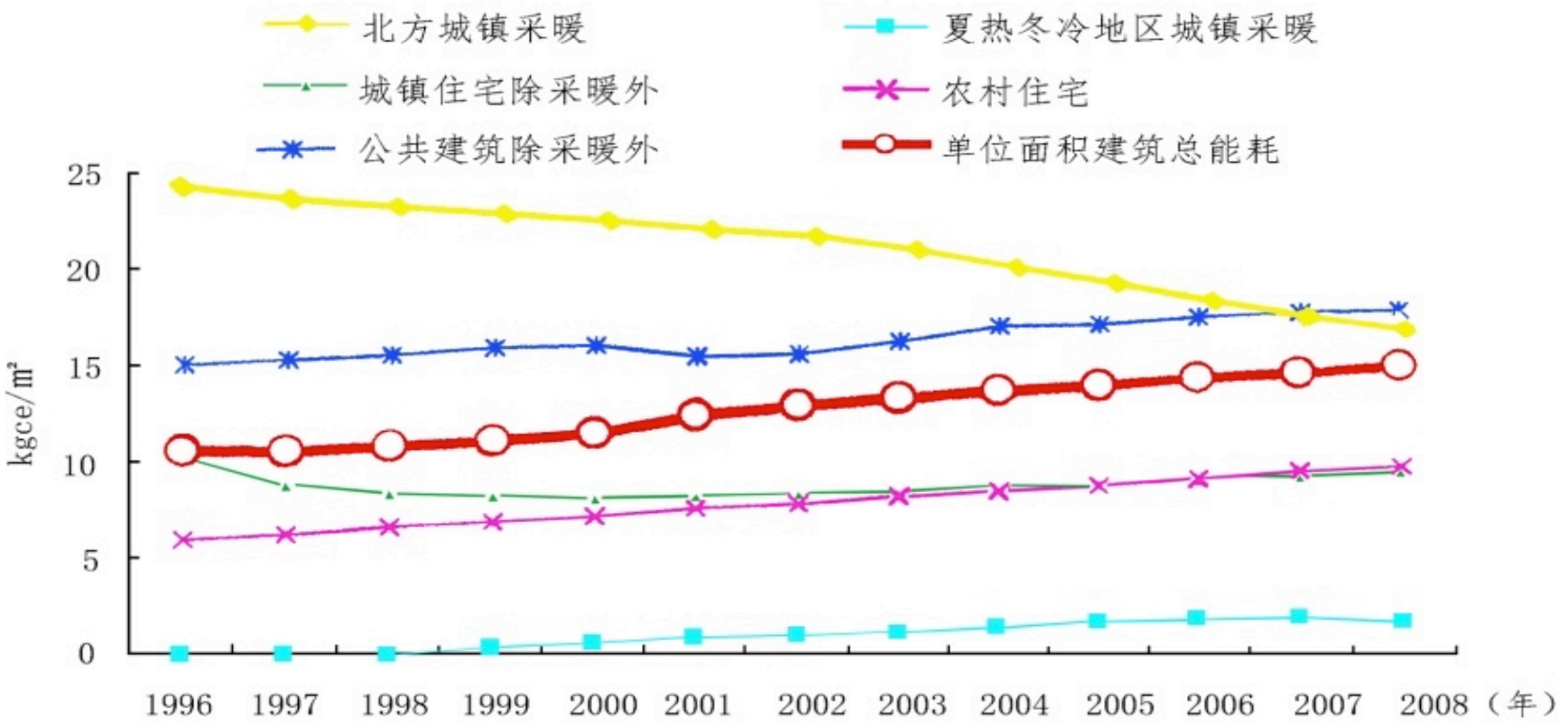
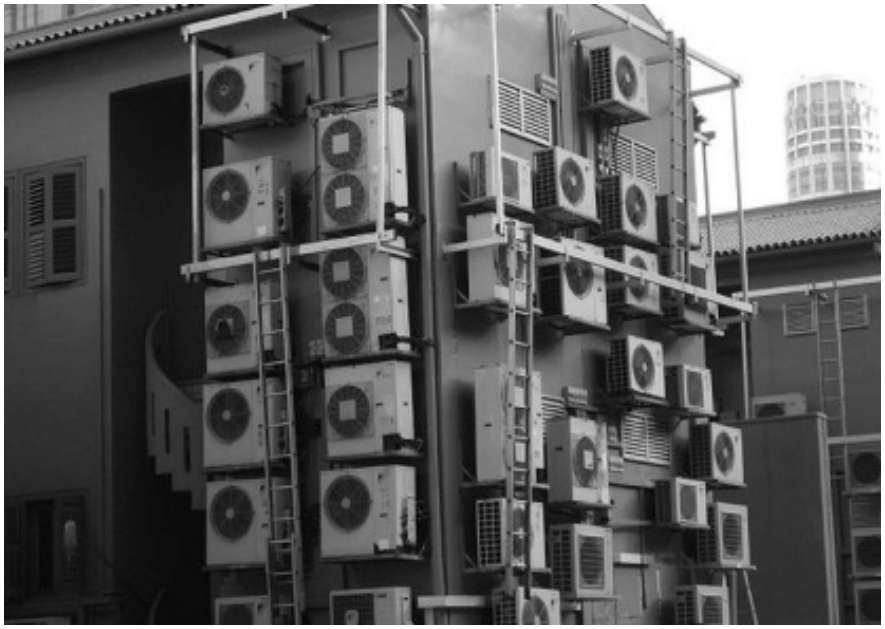


图1-3　各类建筑能耗的单位面积能耗的变化

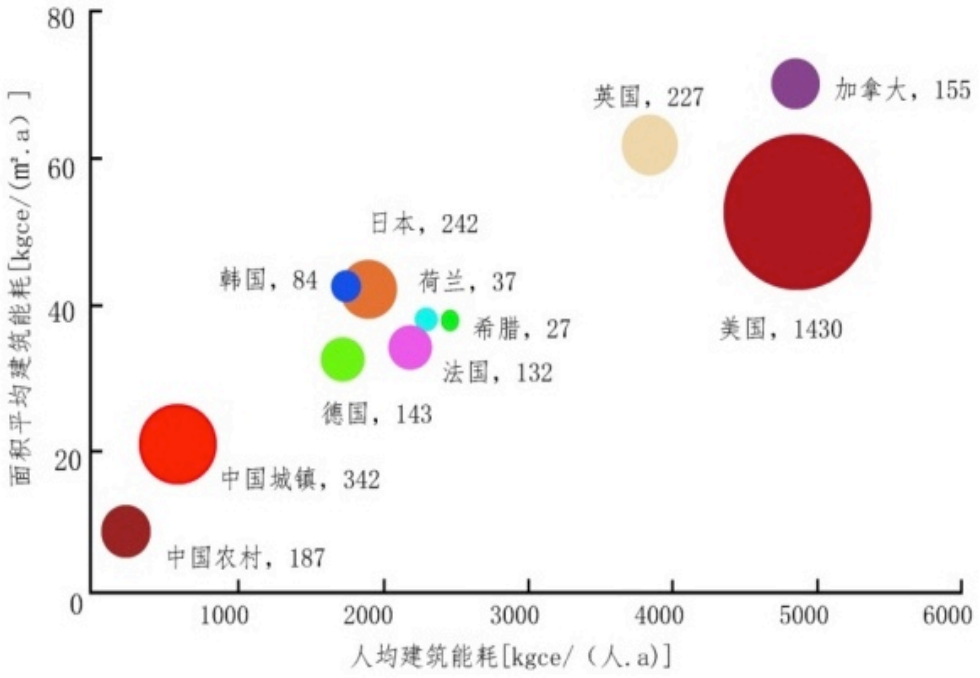
- Building heating energy consumption per unit area is decreasing year by year in north China.
- However, other energy consumption, especial of air-conditioning energy consumption, is increasing rapidly on account of building area growth and living standard improvement.

S3: New Problems



However, new challenges have emerged since the first building energy efficiency standard, one major challenge is the demand for cooling is increasing year after year as people get more disposable income, they demand for higher living standards. Thus building energy efficiency in China need to address cooling and heating now, rather than heating only in the past. In the mean time, 90% residential buildings in China still heavily rely on natural ventilation in swing seasons, which is different from western countries and add complexity in building energy efficient designs.

S3: Specialties in China



- In fact, energy usage intensity (EUI) per square meter/person in China is still far lower than developed counties.

Building energy consumption per person, China vs. Western

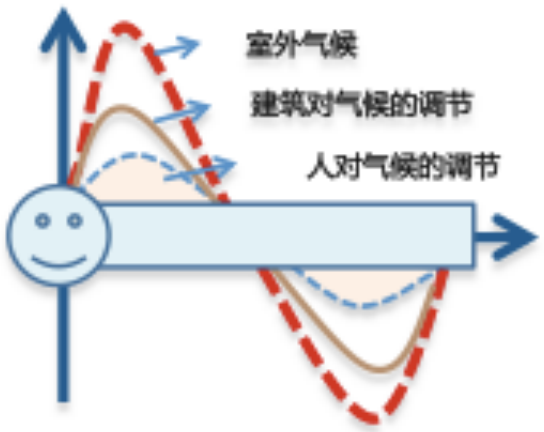
Reasons

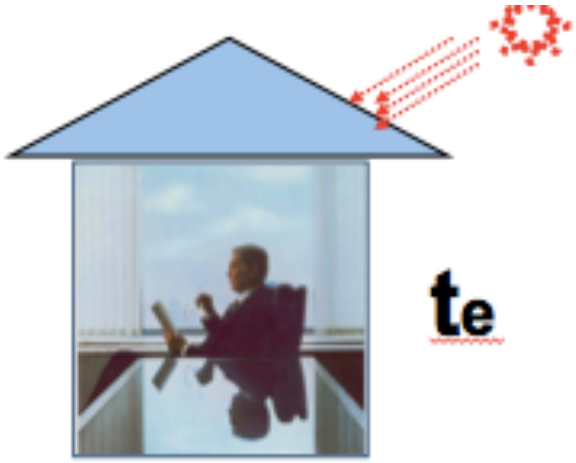
- Mainly because:
- 1) Economical: for a large portion of Chinese people, living standards are still lower than developed countries, thus they couldn't afford the cost of living in a western standard of thermal environment;
- 2) Cultural: a cultural that appreciate a dynamic thermal environment that is closely connected to outdoors;
- If Chinese people would adopt the same thermal comfort standard as their western counterparts, building energy consumption would increase a lot in the future.

And, We’ve already seen the damage made by these standards, large amount of sealed high-rise buildings have been built in China, which consume much more energy than traditional buildings because they rely on air conditioning to control their spaces.

S3: Specialties in China

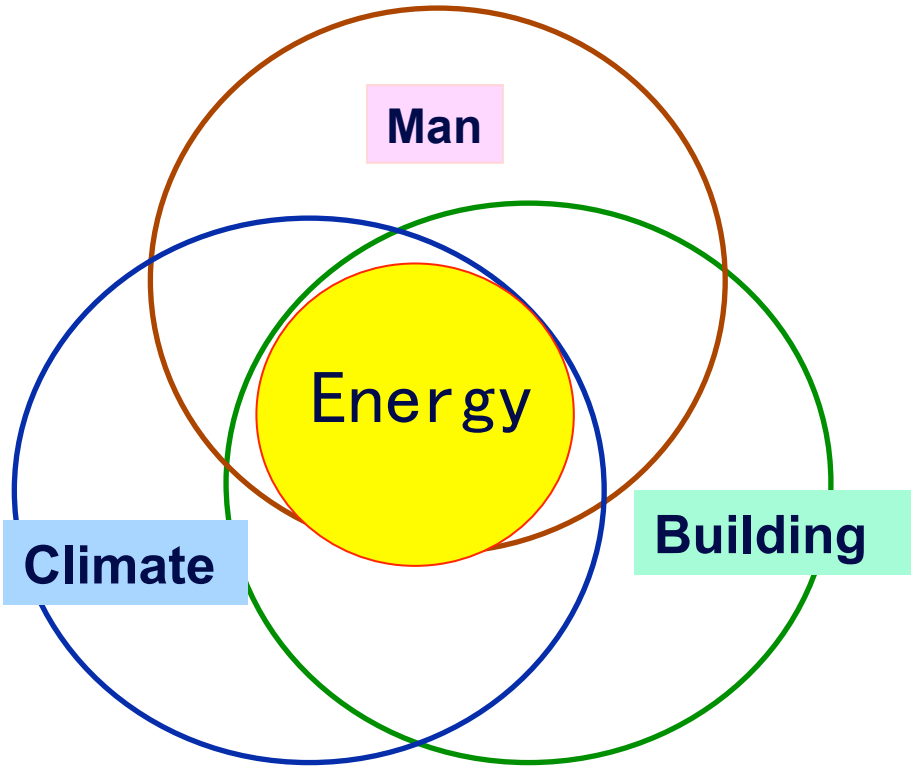
- Dynamic indoor environment make human more adaptive to climate. Chinese are more accustomed or preferred to “Dynamic” indoor environment, and cannot easily accepted “constant temperature and humidity” high thermal environment，therefore，the design strategies for building energy efficiency related to western controlled - environment could not applied



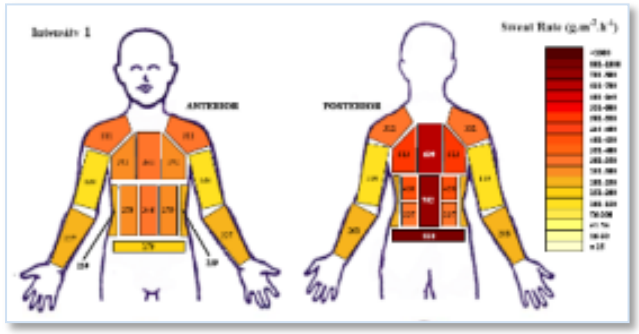


Considerations

So that, the followings considerations, from human, climate and building design aspects, are recommended due to the complexity of building energy efficiency in China:



Considerations



人体基础代谢率　人体与环境换热率　人体热感觉

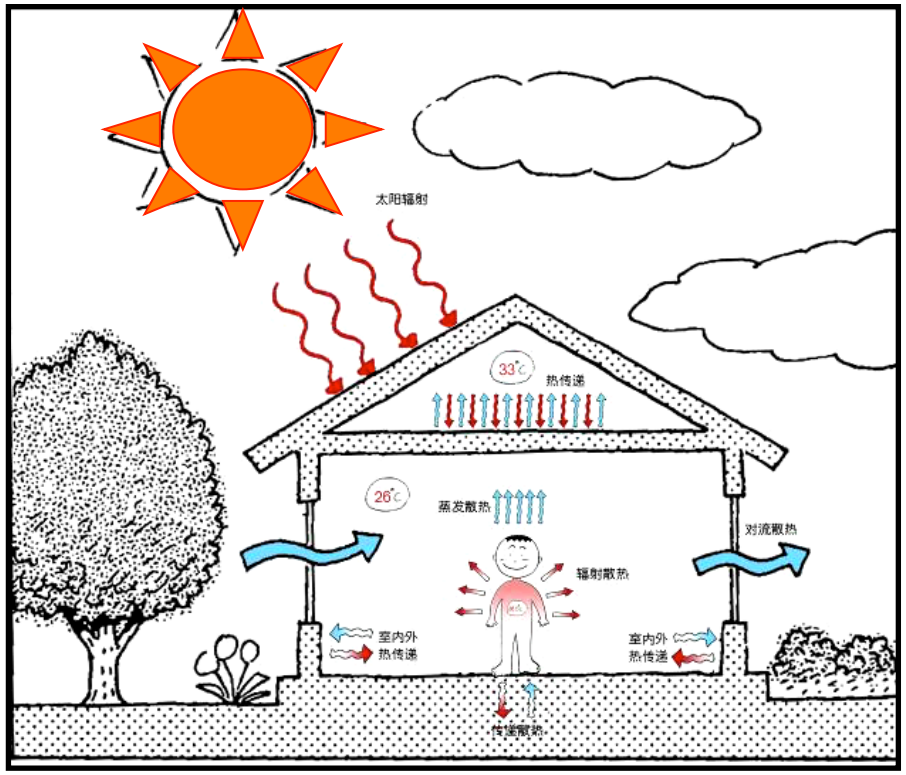
$$E_{base} \pm E_{exchage} = TMV$$

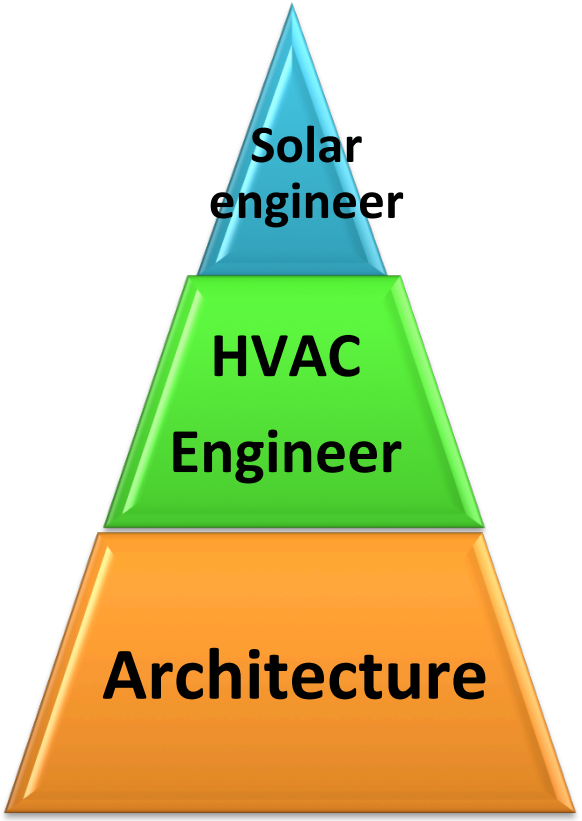
> 0，热

$= 0$，舒适

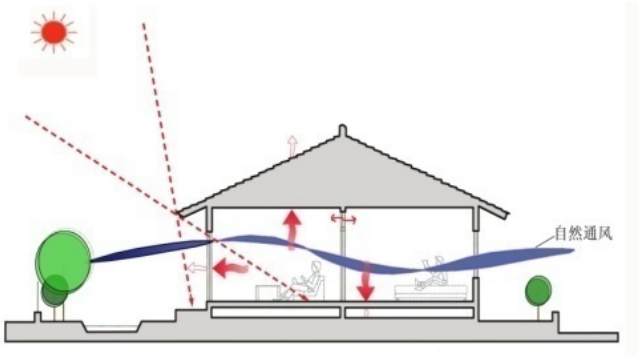
< 0，冷

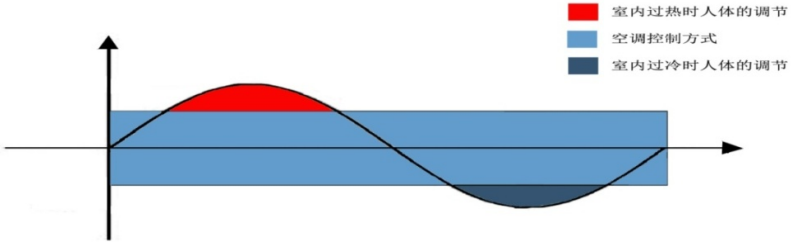
- 1. respect Chinese cultural in, design buildings efficiently to satisfy human physiological and psychological needs,- the “Dynamic”, not constant indoor environment.





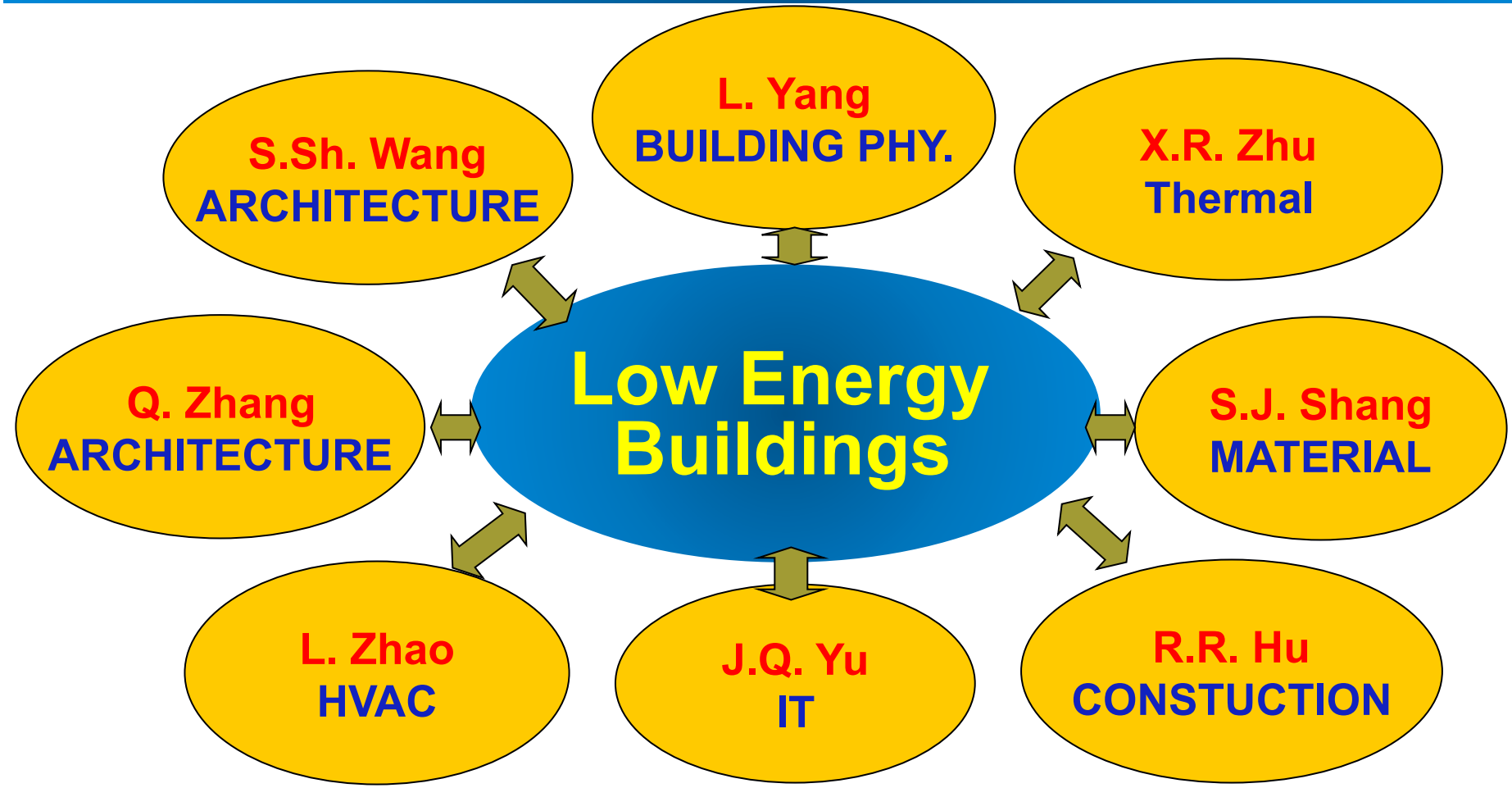
- **Design with Climate：** Unlike high-tech, high-investment low energy building constructed in western, China shall embrace passive designs that adapt to local climate, such as natural ventilation, passive solar, passive cooling to reduce heating/cooling demand.

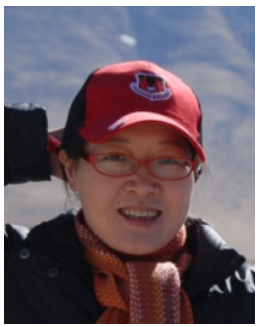
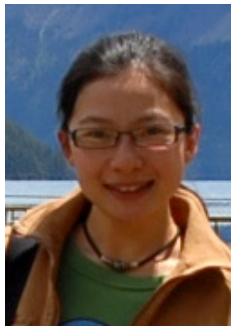


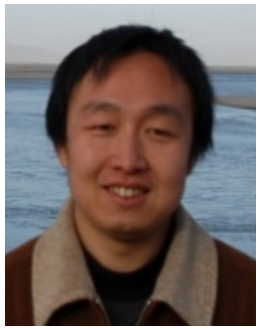


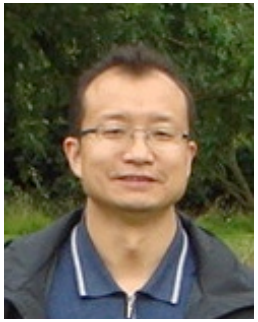
- **Design with local context:** respect Chinese cultural in and traditional building energy design technique. Local human and resources are taken advantaged, and affordable passive design method is well utilized.

multi-discipline research team, including natural, social science and engineers

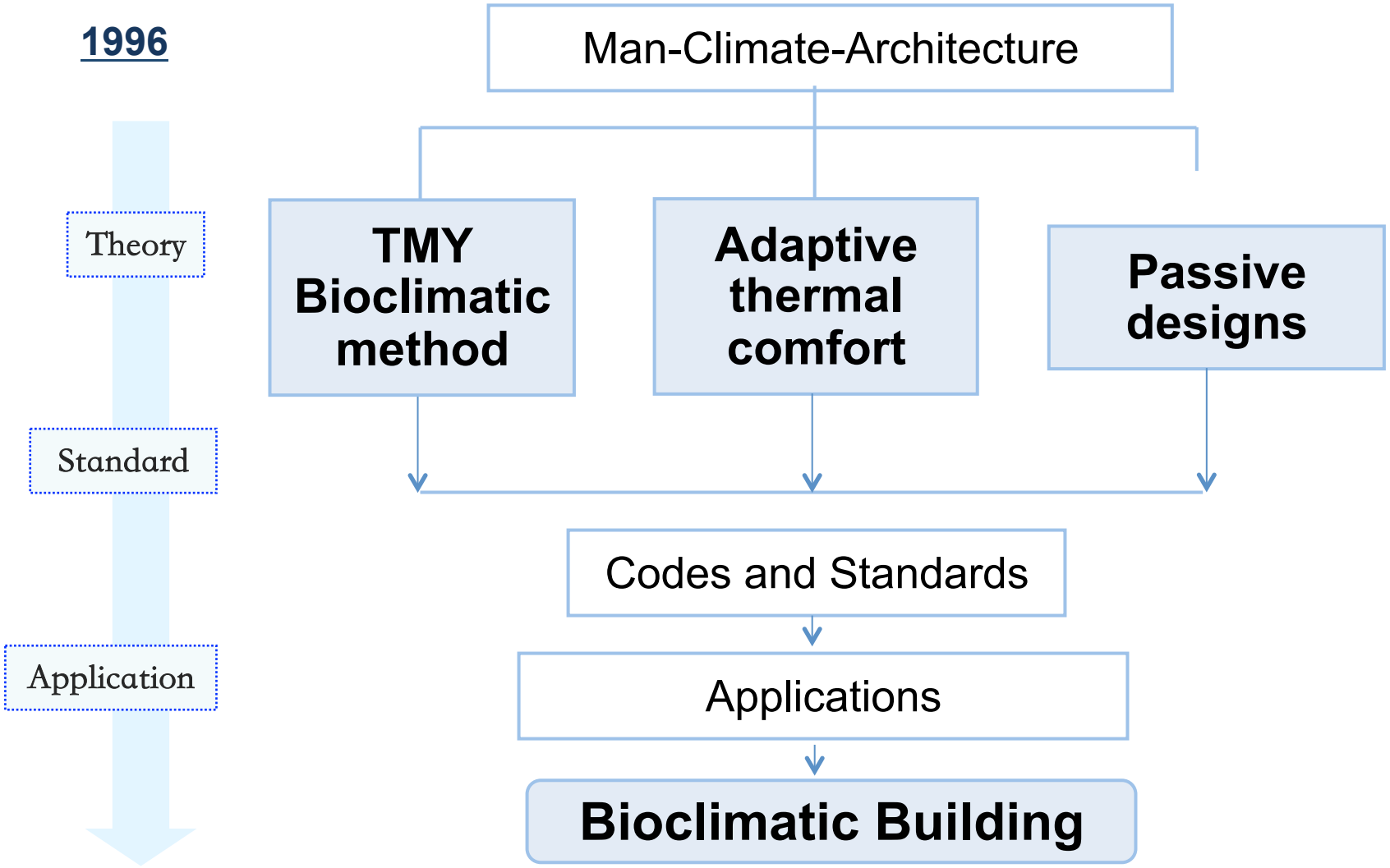


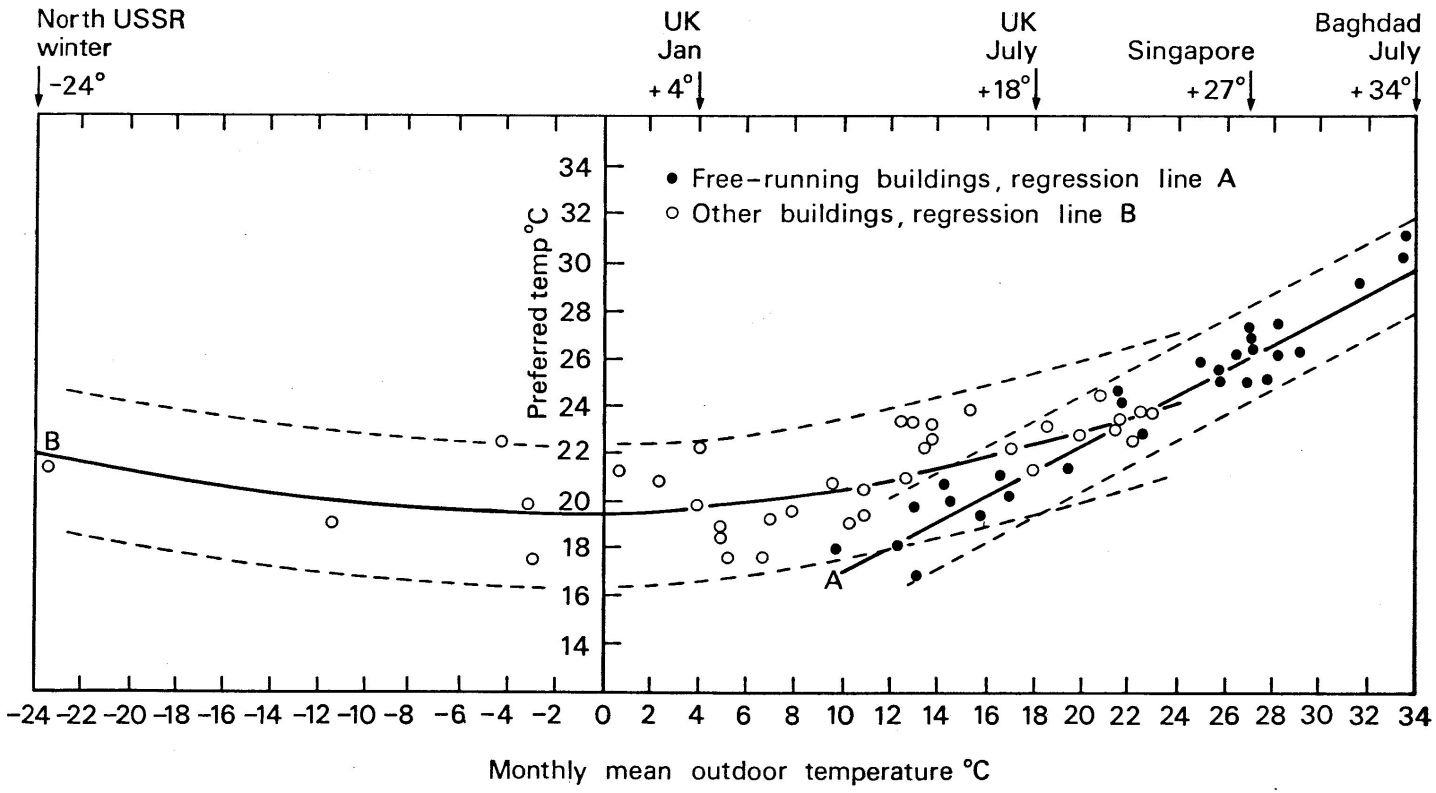


In the past 20 years, with human – climate- building, our research team has developed theory, application and standard on building energy efficiency in China under natural science foundation from China government.



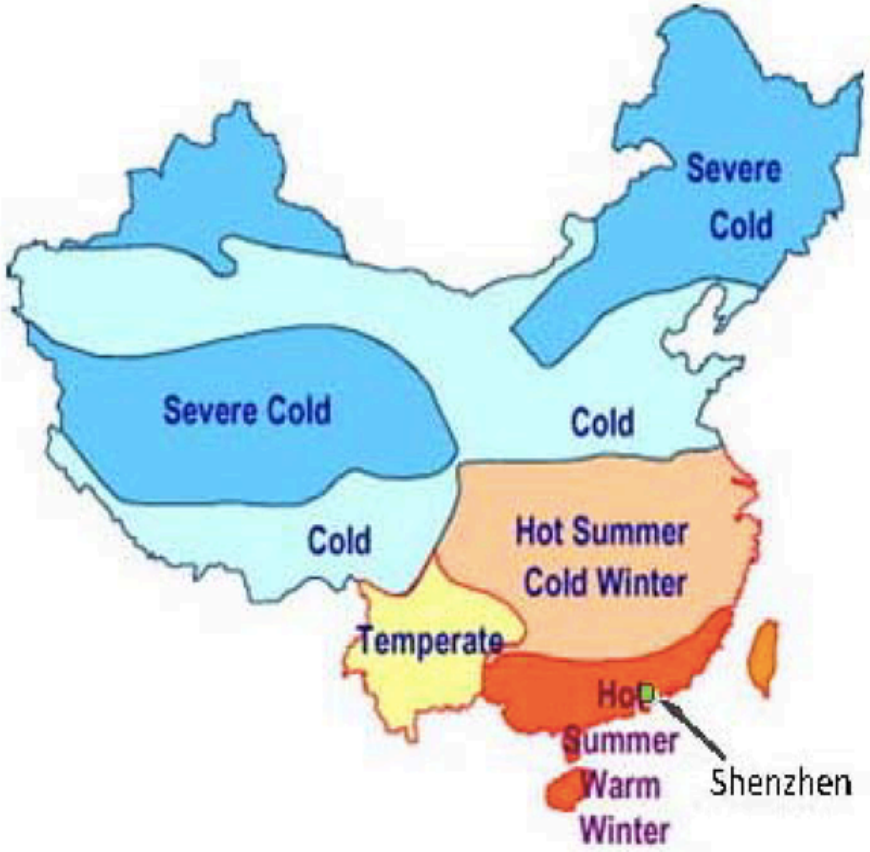
Research

- **Thermal adaptation of Chinese people**



1978年，Humphreys: $T_n=11.9+0.534T_o$

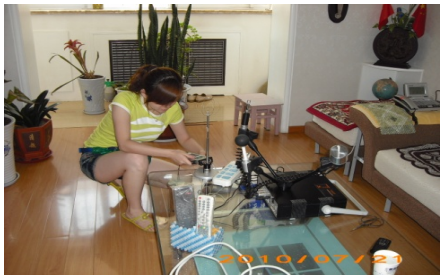
- Research by Humphreys proposed a linear model that connects human comfort temperature and outdoor temperature, which draw the attention of our research team in nineteen nineties. We wonder: 1) are comfort temperature of Chinese related to local climate conditions? China has seven different climate zones that are different from each other, maybe a single comfort standard wouldn't satisfy whole China.



Climate Zones	Mean Monthly Temperature	
	Coldest	Hottest
Severe Cold	≤ -10 °C	≤ 25 °C
Cold	-10 - 0 °C	18-28 °C
HSCW	0- 10 °C	25 - 30 °C
HSWW	>10 °C	25 - 29 °C
Temperate	0 - 13 °F	18 - 25 °C

Thermal adaption

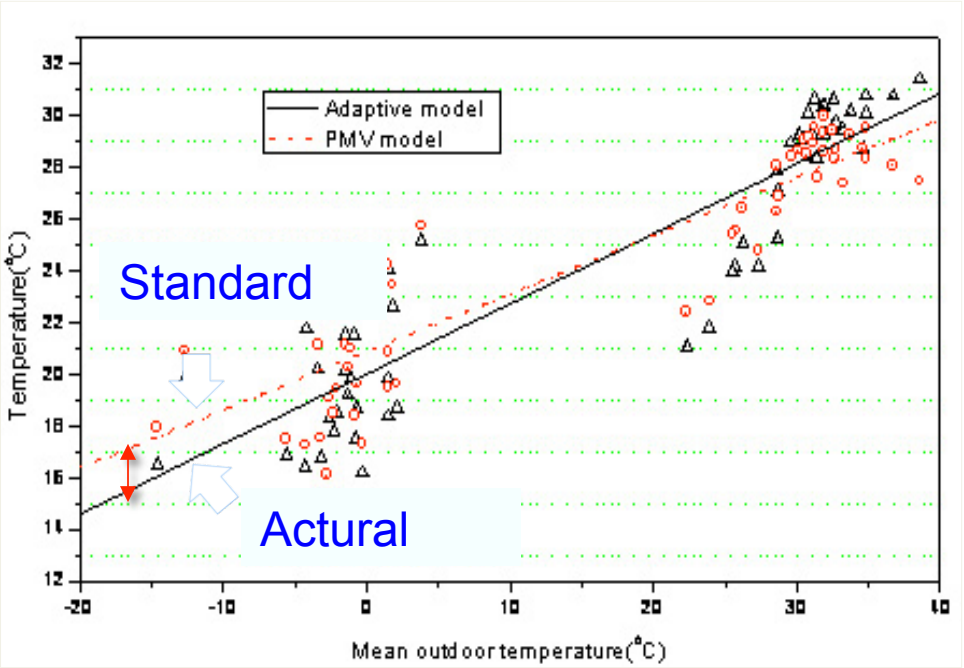
- 2）does Humphreys' models could predict comfort temperature of Chinese people?
- 3）are there any differences in comfort temperatures for different climate zones?
- 4）are there any differences in comfort temperatures for different building types in the same climate zone?
- With these questions in mind, we started our research by conducting thermal comfort field surveys in 20 typical cities that are located in different climate zones.

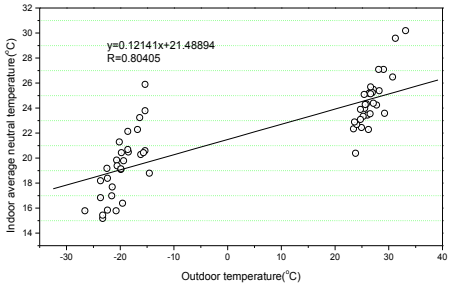


- Measurement study
  - Indoor parameters
  - Outdoor parameters
- Subjective study

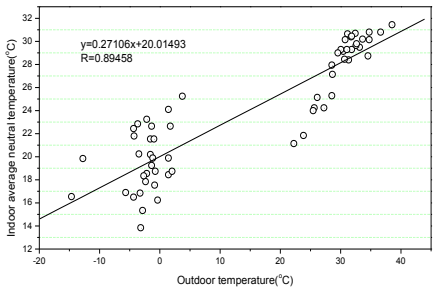
Chinese thermal models

- We found that the adaptive comfort model for Chinese is similar to Humphreys' model, but comfort temperature range for Chinese people are wider in both warm and cool temperatures.

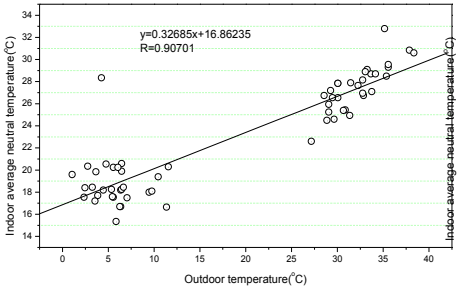




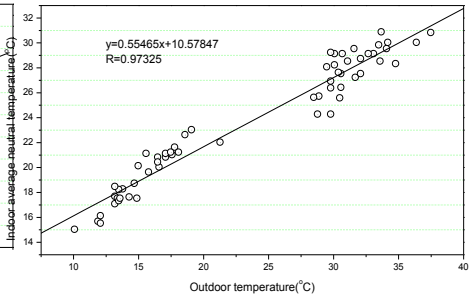
严寒气候



寒冷气候



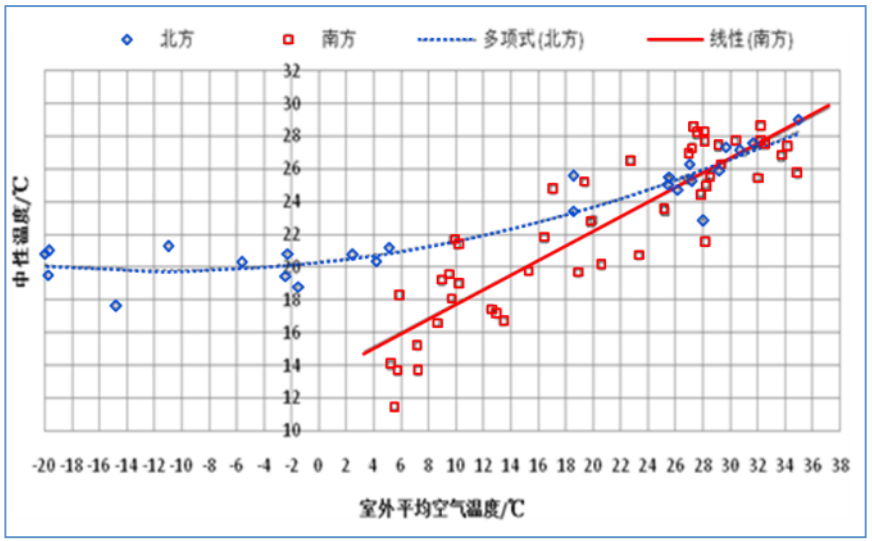
夏热冬冷气候



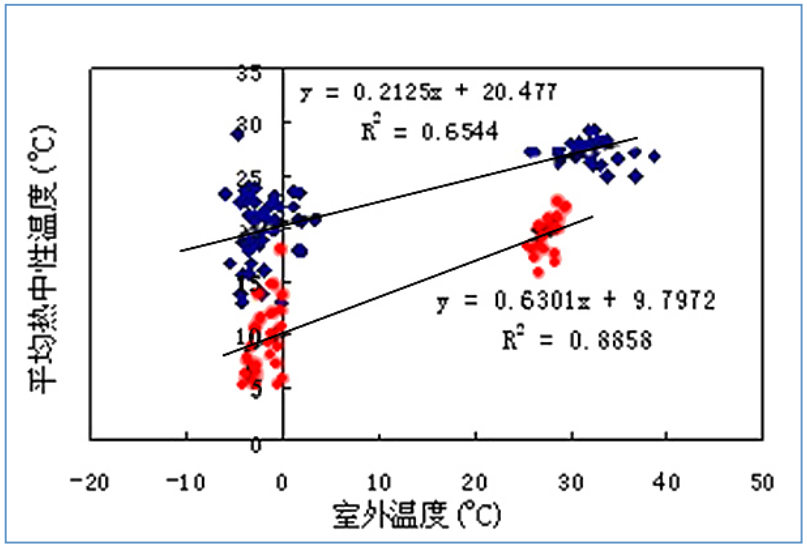
夏热冬暖气候

Chinese thermal models

- Furthermore, we obtained the difference in comfort temperatures for north (central heating) and south (no central heating) China; and the difference of urban and rural area.

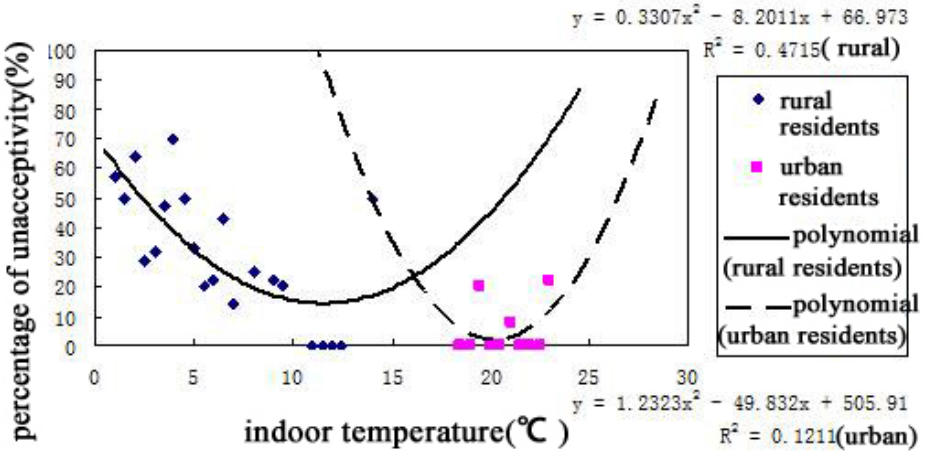


北方人群与南方人群

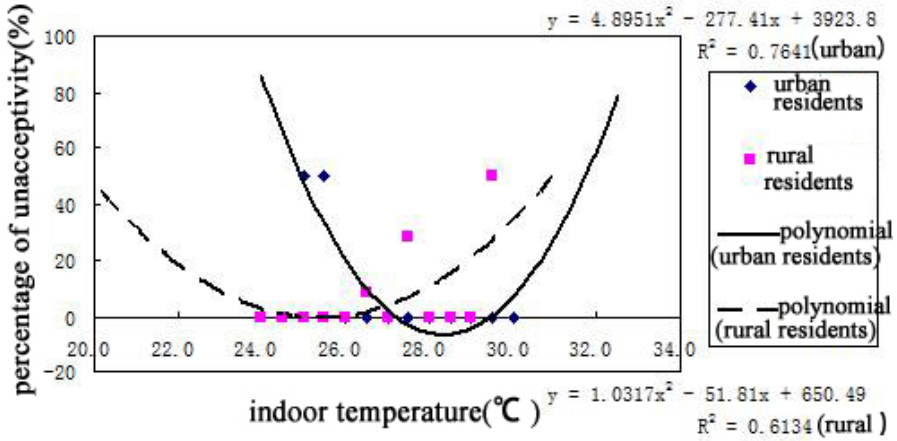


北方城市人群与农村人群

comparison of thermal receptivity



winter:
16.4~24.0℃ for urban residents
0~15.8℃for rural residents



summer:
26.0~30.7℃ for urban residents
20.7~29.5 ℃ for rural residents

application

- Our research findings have been adopted in **Energy conservation design standard for rural residential buildings** (2014),
- which will help providing better comfort and save energy by 8-15%, simply because human adaptation is considered in the design.


中国工程建设标准化协会

公 告

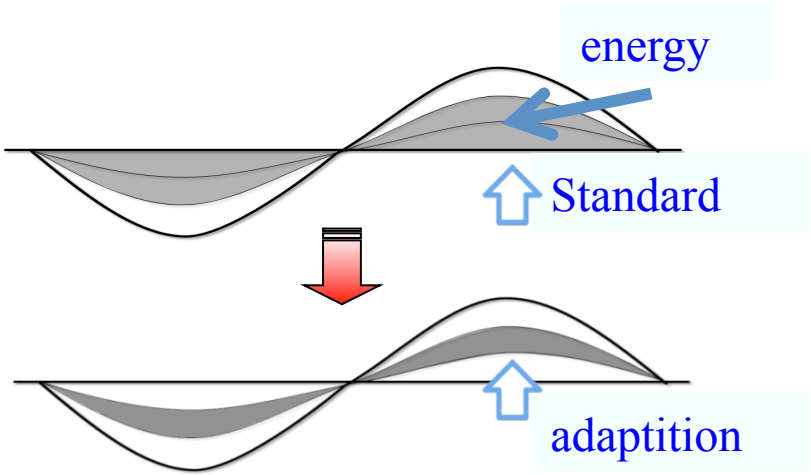
第 125 号

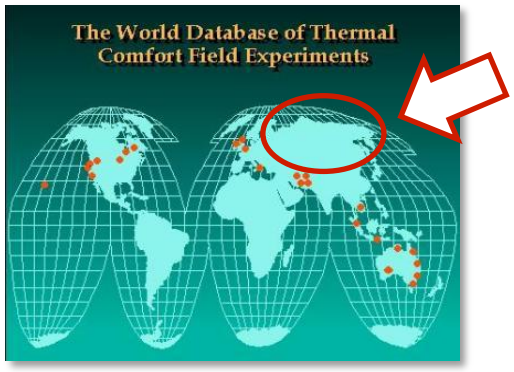
关于发布《农村单体居住建筑节能设计标准》的公告

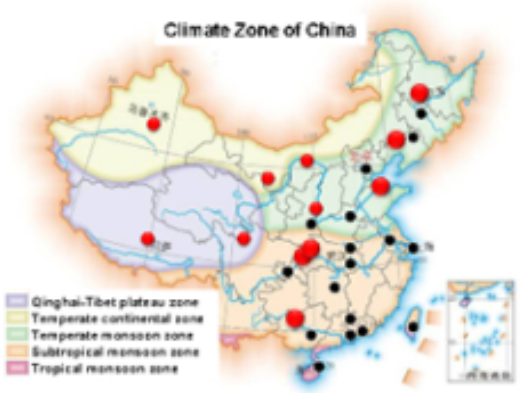
根据中国工程建设标准化协会《关于印发〈2009 年工程建设协会标准制订、修订计划（第三批）〉的通知》（建标协字[2009]90号）的要求，由中国建筑标准设计研究院、清华大学等单位编制的《农村单体居住建筑节能设计标准》，经本协会组织审查，现批准发布，编号为 CECS 332：2012，自 2013 年 2 月 1 日起施行。

二〇一二年十月十一日

Energy efficiency of different regions		
Climate zones	**city**	**saving**
severe cold	**Harbin**	**7.3**
cold	**Beijing**	**14.8**
HSACW	**Shanghai**	**12.3**
HSAWW	**Guangzhou**	**12.5**
mild	**Kunming**	**8.3**







- **ASHRAE**
- **ANNEX 69**

EBC
Energy in Buildings and Communities Programme

ANNEX 69

Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings

(Mid-Term Preparation Phase Status Report)

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Tsinghua University
China

Richard de Dear
The University of Sydney
Australia

June 18-19, 2015 @ Lisbon, Portugal

Participants

- **28** institutes, representing **12** countries

	Country	Researcher	Institution
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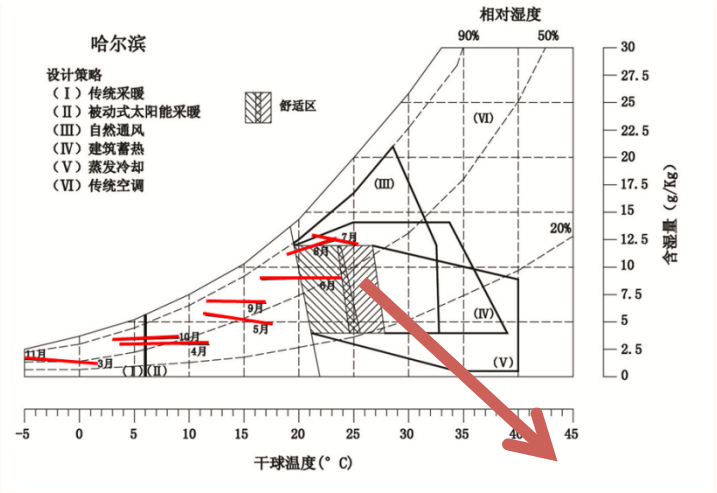
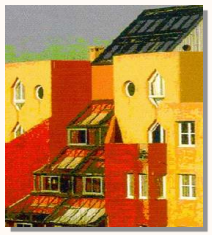
3	China	Bin Cao	Tsinghua University
4	China	Qin Ouyang	Tsinghua University
5	China	Liu Yang	Xi'an University of Architecture and Technology
6	China	Zhaojun Wang	Harbin Institute of Technology
7	China	Yufeng Zhang	South China University of Technology
8	China	Xiang Zhou	Tongji University
9	Denmark	Bjarne Olesen	Technical University of Denmark
10	Denmark	Jorn Toftum	Technical University of Denmark
11	Denmark	Henrik N. Kundsen	Aalborg University
12	Germany	Marcel Schweiker	Karlsruhe Institute of Technology
13	Germany	Andreas Wagner	Karlsruhe Institute of Technology
14	Japan	Hiroshi Yoshino	Tohoku University
15	Japan	Tomonobu Goto	Tohoku University
16	Japan	Shinichi Tanabe	Waseda University
17	Japan	Ryozo Ooka	The University of Tokyo
18	Japan	Hom Rijal	Tokyo City University
19	Japan	Kazuyo Tsuzuki	National Institute of Advanced Industrial Science and Technology
20	Korea	Chungyoon Chun	Yonsei University

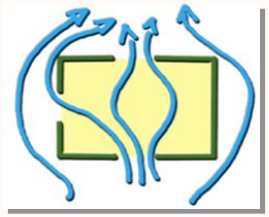
Climate

- 1 Bioclimatic building design method
- 2 Typical meteorological years for Building simulation

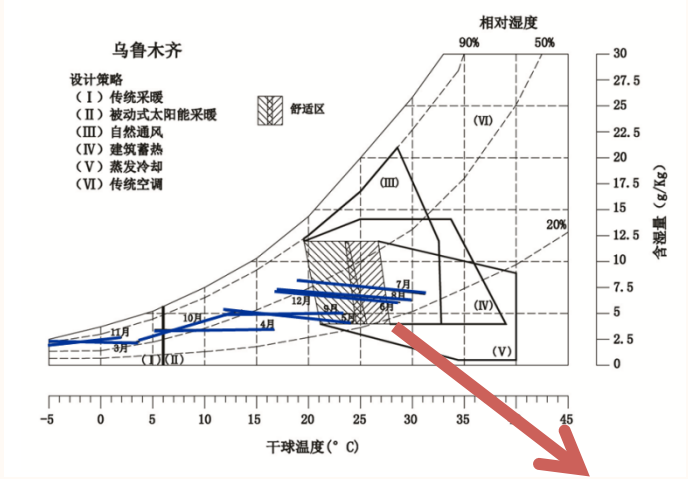
We introduced the concept of Bioclimatic Design into China, and developed tools to help architects quantify the effect of climate on different design strategies. For instance, the cooling methods could be different for hot-dry climate or hot-humid climate

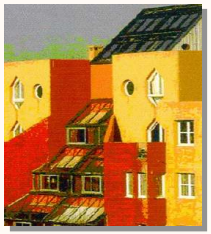






Solar + Ventilation

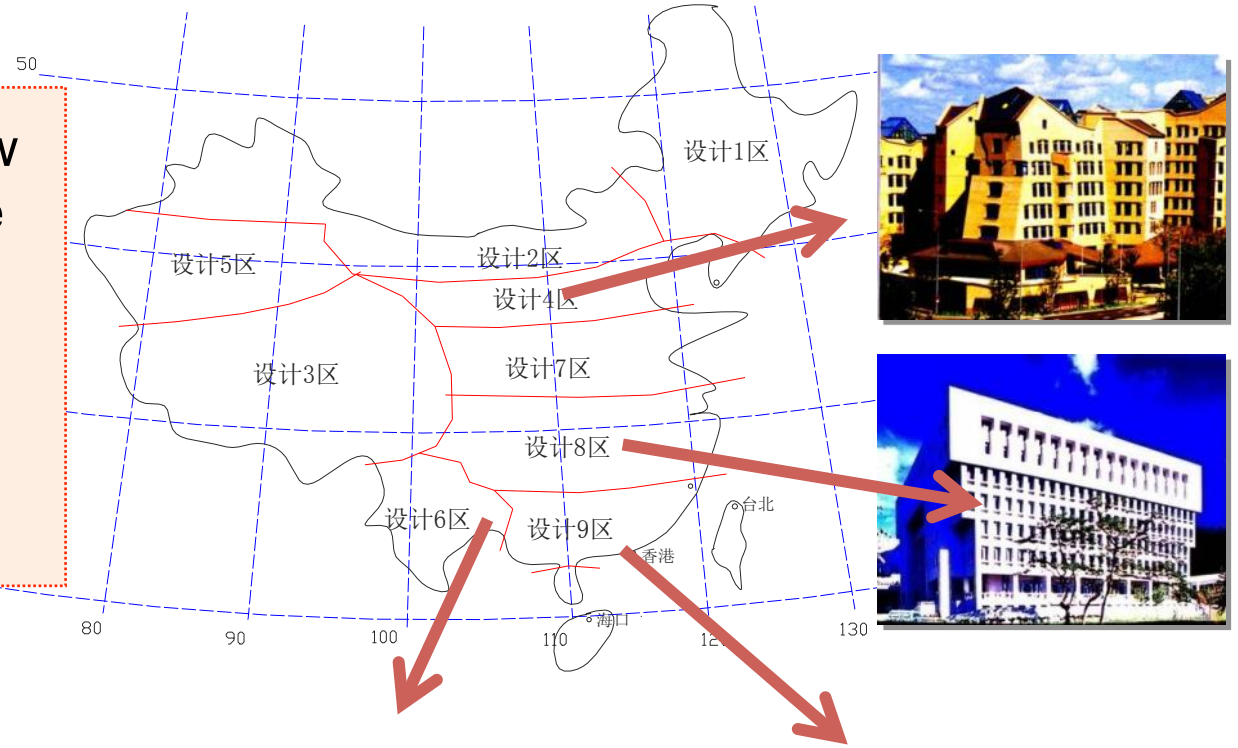




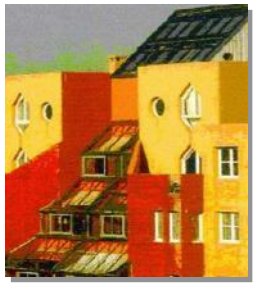
Solar + Thermal Mass

Passive building design climate map

We also proposed a new climate zone for passive buildings design, which could help architects chose suitable passive design strategies for different climates.

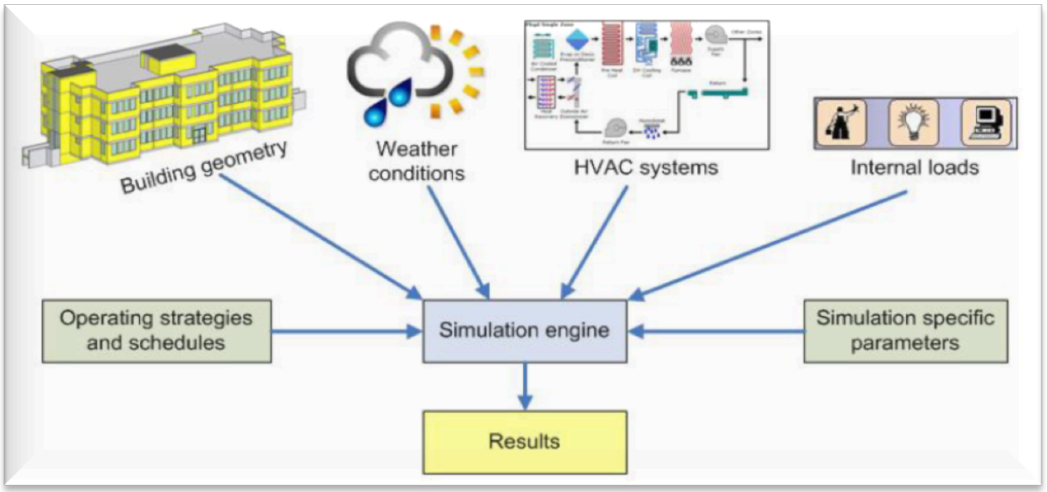


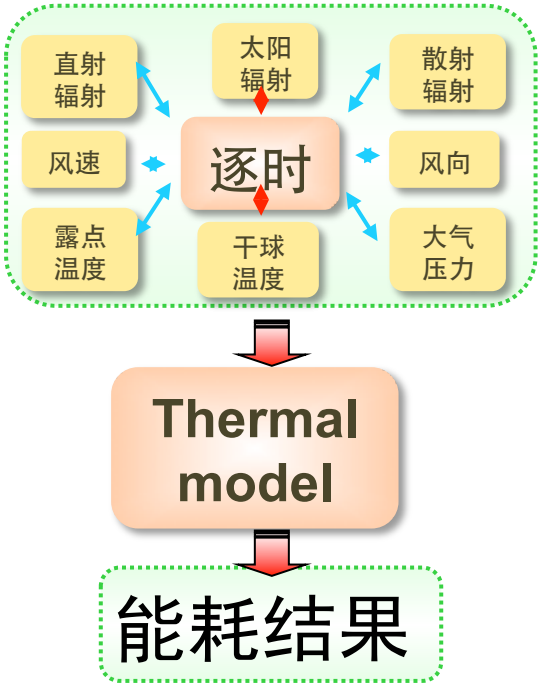
〈*Energy Conversion and Management*〉, 2006, Vol.47(6), 746-762



TMYs Research

2. Study on Typical Meteorological Year (TMY). TMY is essential for building energy modeling, however, there were no TMY for China until 2000. Thus no building energy simulation could be done before 2000.

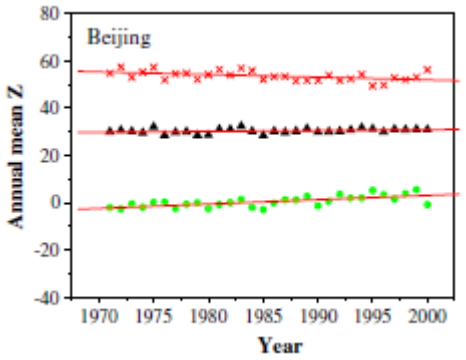


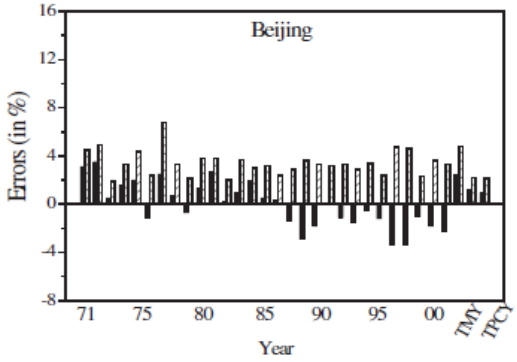


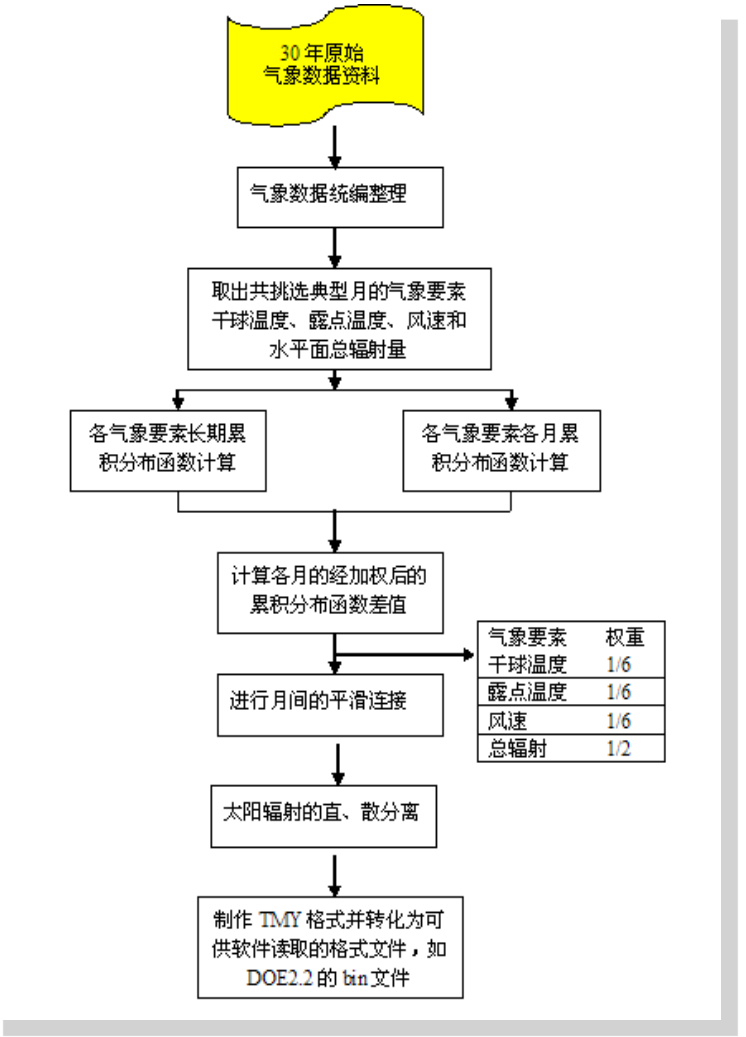
TMY method

- To fill the gap, we developed TMY for 450 cities through analyzing the weather data obtained from China Meteorological Station. It reflects the spatial climate distribution in China, and could be used to evaluate the effect of climate on building energy consumption. :

$$Z = a \cdot Td + b \cdot Tw + c \cdot Sg$$

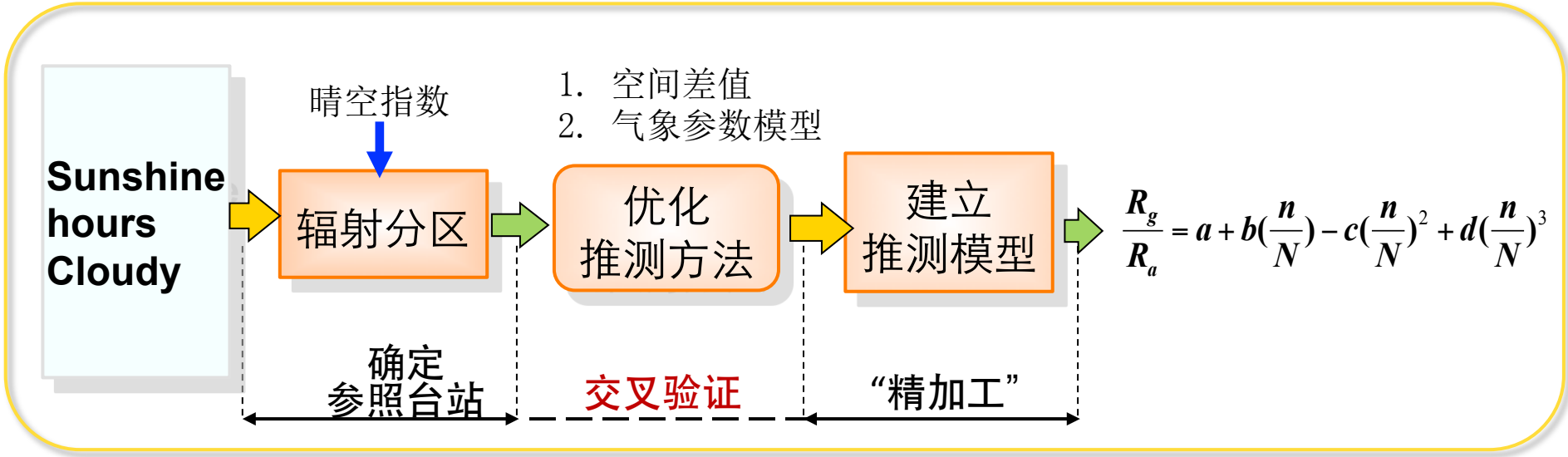


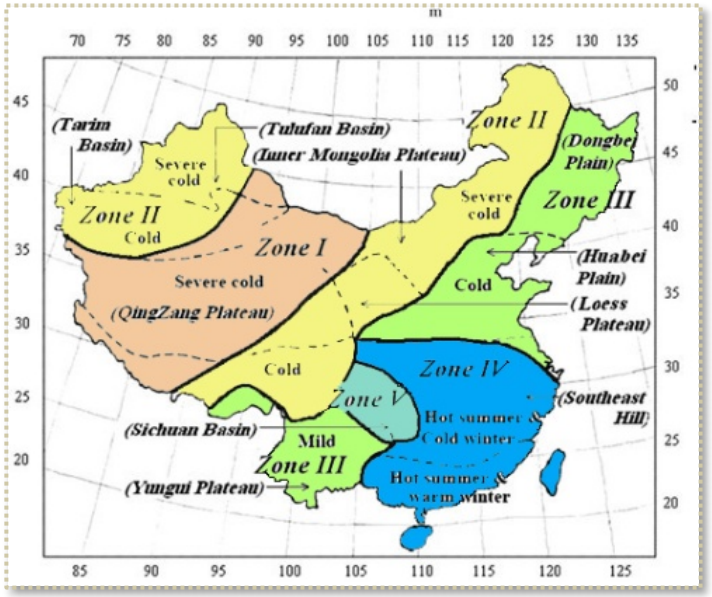


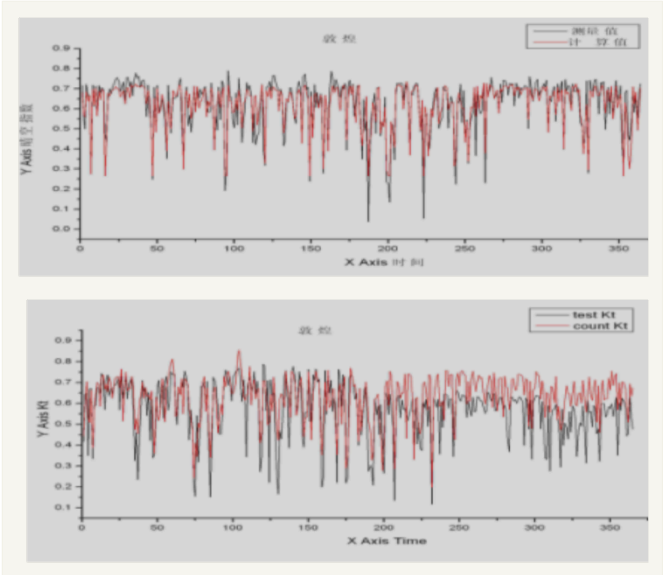


气象年的生成过程

Solar Radiation model







Standards and Data Base

- Database has been developed using Web technology, including fundamental climate information for building efficient design.

Application

- more than 20 projects of Green Building Design

Residents

Public building

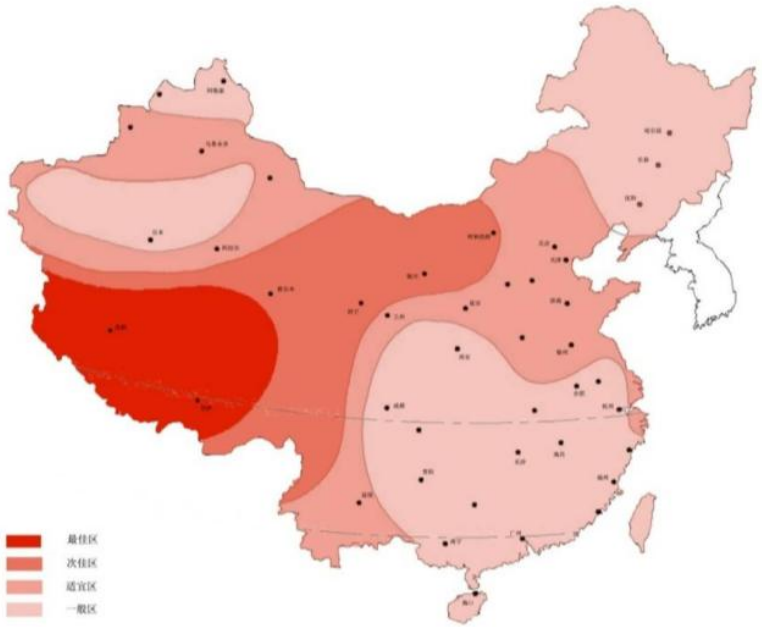
Culture Building

Application research

- Passive building design research in two extreme climates of China

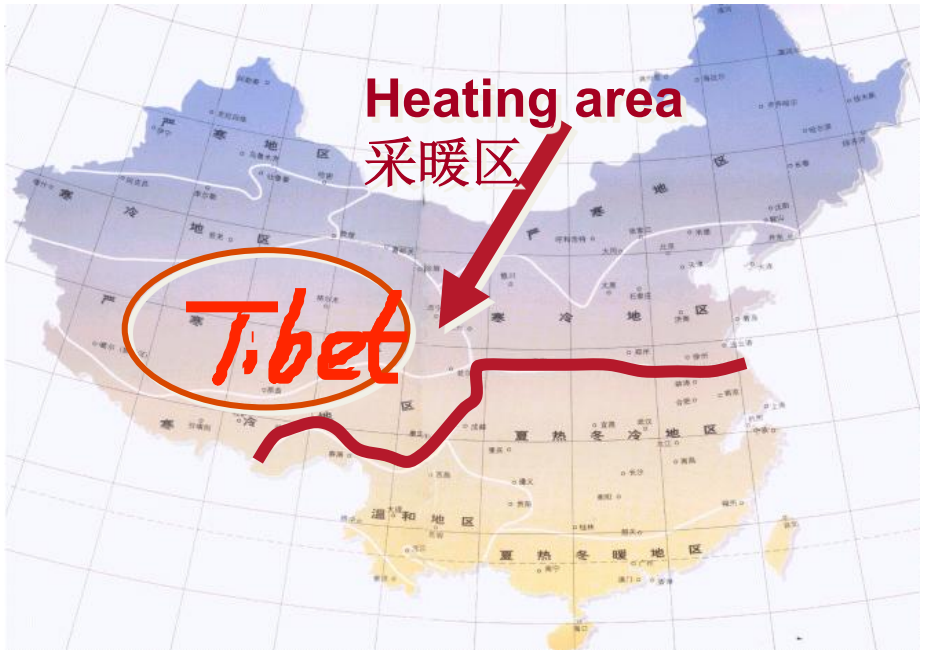
Passive solar design in Tibet Plateau

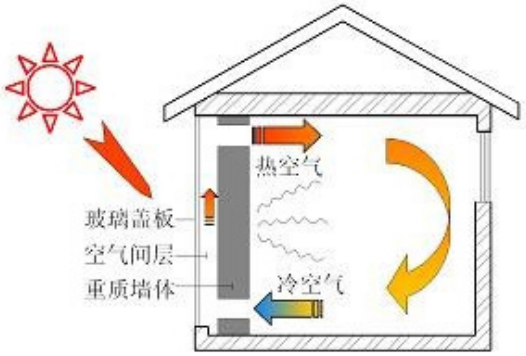
- Tibet, due to its unique geographical characteristics, is cold in winter, cool in summer and generally dry. Sunlight is extremely intense. Tibet has very limited fossil fuel resources for heating in winter, thus central heating is not an option for energy efficient building designs. However, buildings with comfort indoor temperatures are important of Tibetan people's life and happiness.

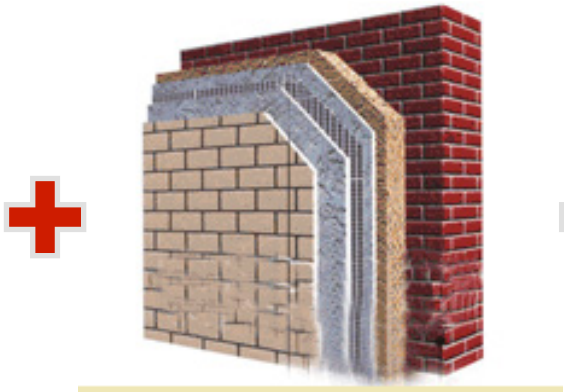


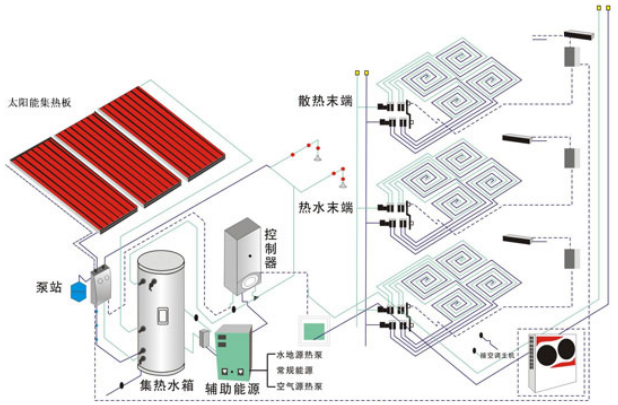
Heating solution

- After years of investigation we decided to design residential buildings first by adding insulation to the envelope, plus passive solar design, supported by active solar when passive solar is insufficient to maintain proper indoor temperature. By those means we were able to achieve zero fossil fuel consumption in such buildings.





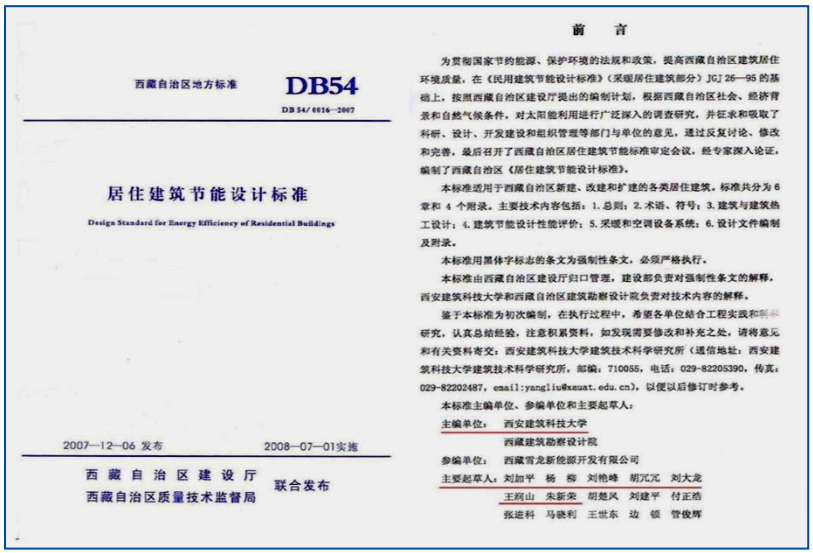




Design standard

Based on these successful achievements we proposed a building energy efficient standard for Tibet, which is the first building energy efficient standard that adopts district heating using solar power.

…The standard will be filling a gap that there is not standard for construction engineering in Tibet Plateau, which would be the first standard of building efficiency of solar district heating in China.



西藏自治区地方标准 DB54

DB 54/ 0016—2007

居住建筑节能设计标准

Design Standard for Energy Efficiency of Residential Buildings

2007—12—06 发布 2008—07—01实施

西藏自治区建设厅 西藏自治区质量技术监督局 联合发布

前 言

为贯彻国家节约能源、保护环境的法规和政策，提高西藏自治区建筑居住环境质量，在《民用建筑节能设计标准》（采暖居住建筑部分）JGJ 26—95 的基础上，按照西藏自治区建设厅提出的编制计划，根据西藏自治区社会、经济背景和自然气候条件，对太阳能利用进行广泛深入的调查研究，并征求和吸取了科研、设计、开发建设和组织管理等部门与单位的意见，通过反复讨论、修改和完善，最后召开了西藏自治区居住建筑节能标准审定会议，经专家深入论证，编制了西藏自治区《居住建筑节能设计标准》。

本标准适用于西藏自治区新建、改建和扩建的各类居住建筑。标准共分为 6 章和 4 个附录。主要技术内容包括：1. 总则；2. 术语、符号；3. 建筑与建筑热工设计；4. 建筑节能设计性能评价；5. 采暖和空调设备系统；6. 设计文件编制及附录。

本标准用黑体字标志的条文为强制性条文，必须严格执行。

本标准由西藏自治区建设厅归口管理，建设部负责对强制性条文的解释，西安建筑科技大学和西藏自治区建筑勘察设计院负责对技术内容的解释。

鉴于本标准为初次编制，在执行过程中，希望各单位结合工程实践和[illegible]研究，认真总结经验，注意积累资料，如发现需要修改和补充之处，请将意见和有关资料寄交：西安建筑科技大学建筑技术科学研究所（通信地址：西安建筑科技大学建筑技术科学研究所，邮编：710055，电话：029-82205390，传真：029-82202487，email:yangliu@xauat.edu.cn），以便以后修订时参考。

本标准主编单位、参编单位和主要起草人：

主编单位： 西安建筑科技大学

西藏建筑勘察设计院

参编单位： 西藏雪龙新能源开发有限公司

主要起草人：刘加平 杨 柳 刘艳峰 胡冗冗 刘大龙

王祝山 朱新荣 胡楚风 刘建平 付正浩

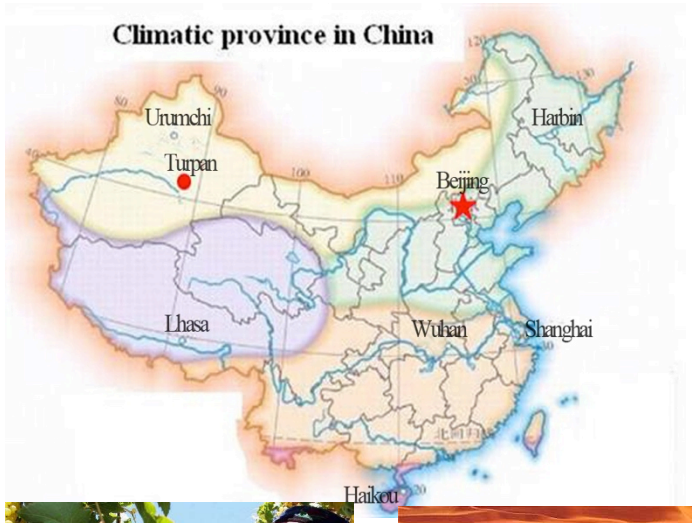
张进科 马晓利 王世东 边 疆 管俊辉

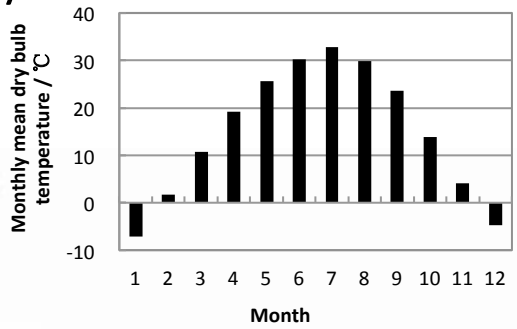
Application

- Furthermore, we constructed 40,000 square meter solar houses in cold Tibet plateau.

Second case

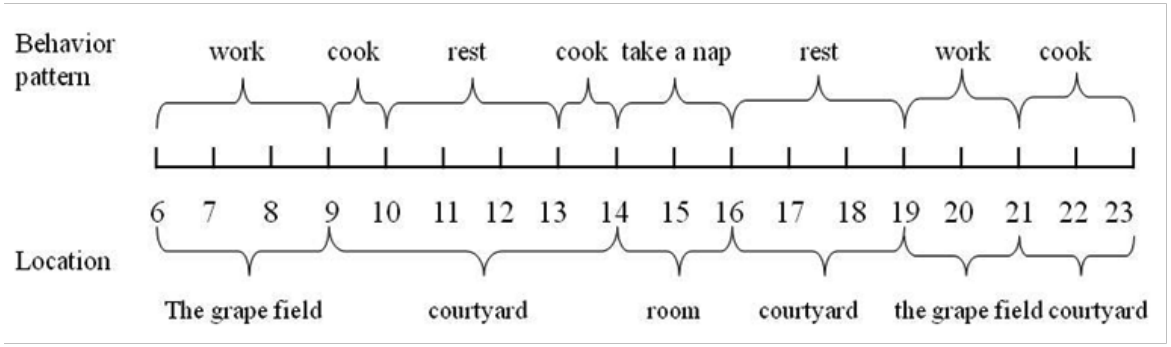
- is in the China's north west, rural area. City names Turpan, the worlds lowest basin-turpan Basin in Xinjiang. At Turpan City, summer is hot and dry with large diurnal variation and winter is cold. Sunlight is intense so here is the hottest area in China， commonly known as "the Land of Fire".





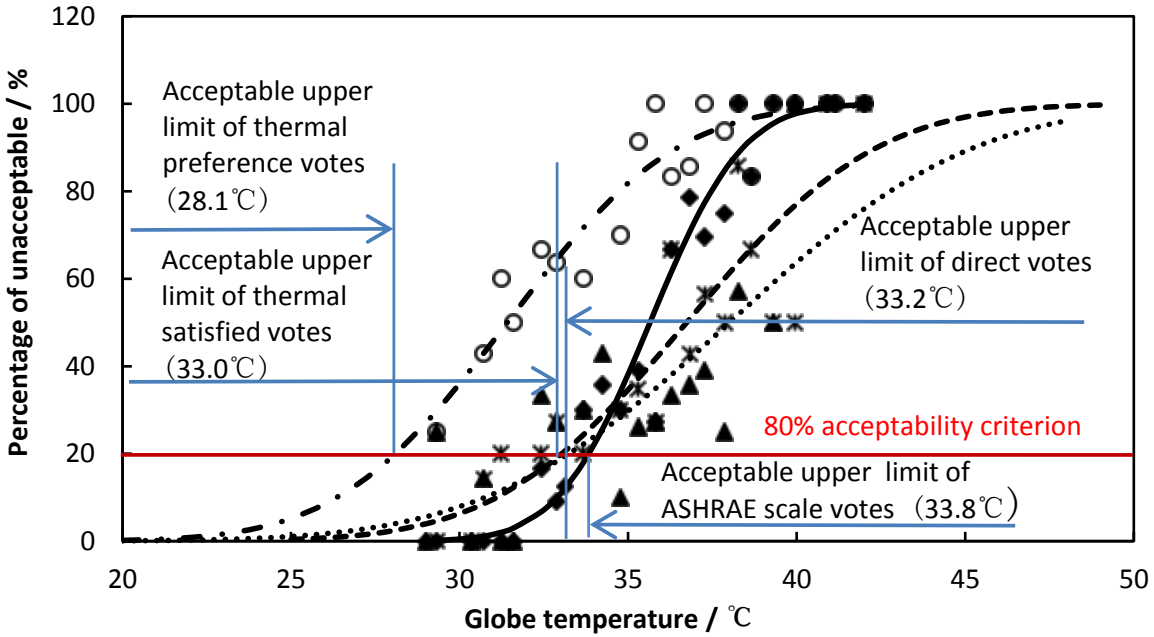
Elevation: -155m

- People adapt local hot climate using their own ways, including behavior and physiological actions.
- such as staying the shaded court yard most time of the day, sleeping outdoors.



the original house is one-story adobe building. Space living and safety are not satisfied by residents. To improve the housing condition for Turpan people, the local government provide 20,000 Yuan ($ 3000) for each household to retrofit/rebuild there houses. However, building a new house may cause over 100,000 Yuan ($15,000), which is the upper limit that local people could afford. So the challenge here is to design a house that maintain reasonable temperature in extreme heat/cold and dry climate with very limited budget.

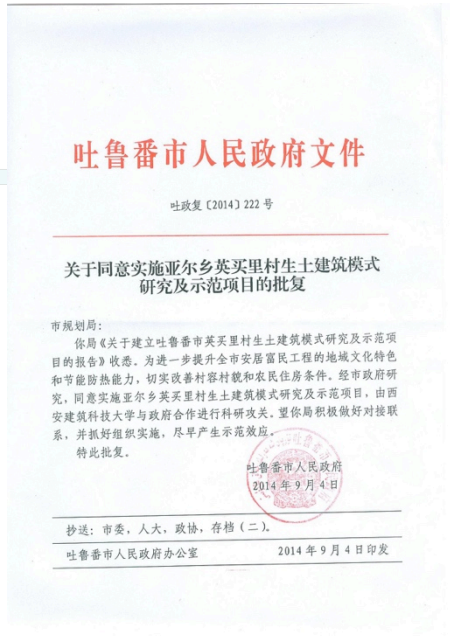
Thermal comfort investigation



We started the project by investigating thermal comfort requirement of local people via field surveys. We found that the neutral temperature is found at 29.7C (summer), which is far higher than the comfort zone specified by ISO7730 (2005) or ASHRAE Standard 55 (2004). This makes bold passive design possible in such a hot-dry climate.

Design Ideas

1. We reserved traditional design methods such as shaded courtyard for summer cooling, underground basement for winter warming, also using adobe, which is a high thermal inertia traditional building material.



吐鲁番市人民政府文件

吐政复〔2014〕222号

关于同意实施亚尔乡英买里村生土建筑模式研究及示范项目的批复

市规划局：

你局《关于建立吐鲁番市英买里村生土建筑模式研究及示范项目的报告》收悉。为进一步提升全市安居富民工程的地域文化特色和节能防热能力，切实改善村容村貌和农民住房条件。经市政府研究，同意实施亚尔乡英买里村生土建筑模式研究及示范项目，由西安建筑科技大学与政府合作进行科研攻关。望你局积极做好对接联系，并抓好组织实施，尽早产生示范效应。

特此批复。

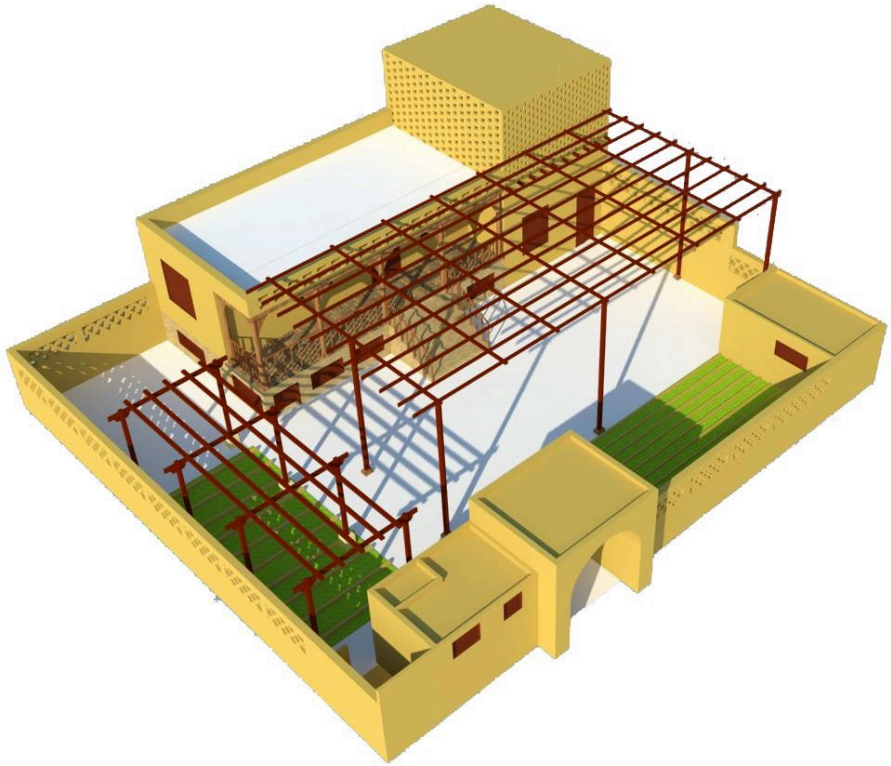
吐鲁番市人民政府

2014年9月4日

抄送：市委，人大，政协，存档（二）。

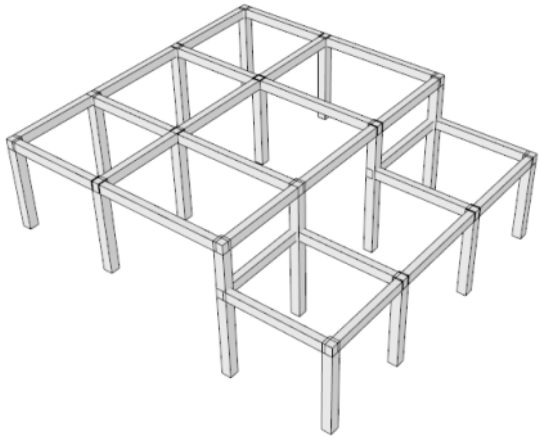
吐鲁番市人民政府办公室　　2014年9月4日印发

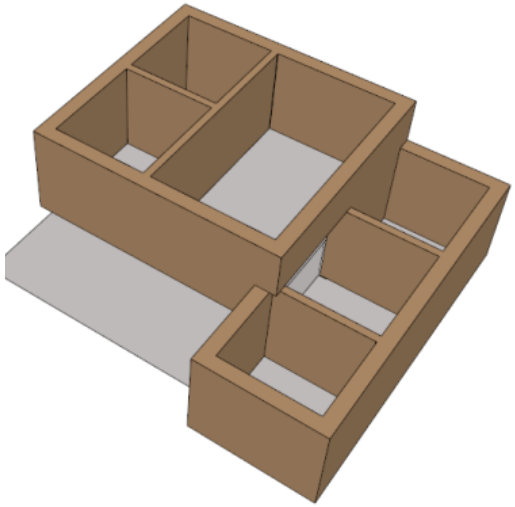
2. In addition to the above-mentioned traditional methods, we introduced cool roof, designed night ventilation construction.
3. We also introduced an adobe-based frame structure to ensure safety with low cost.



PLAN A

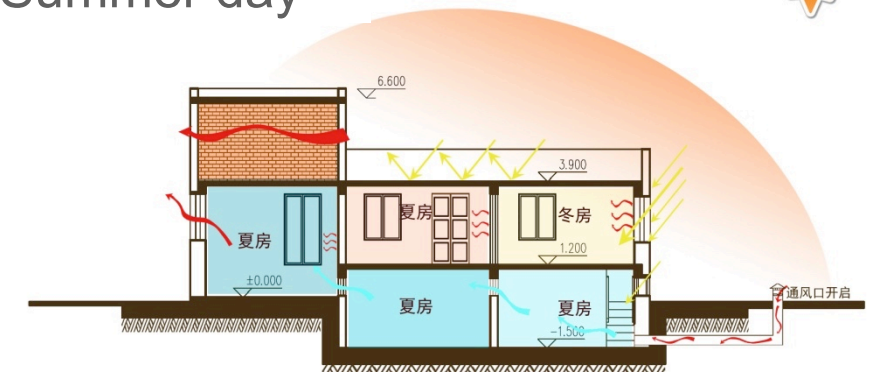
- First Floor Area 87.5 ㎡
- Living room, and three
- Cost: 47 000元



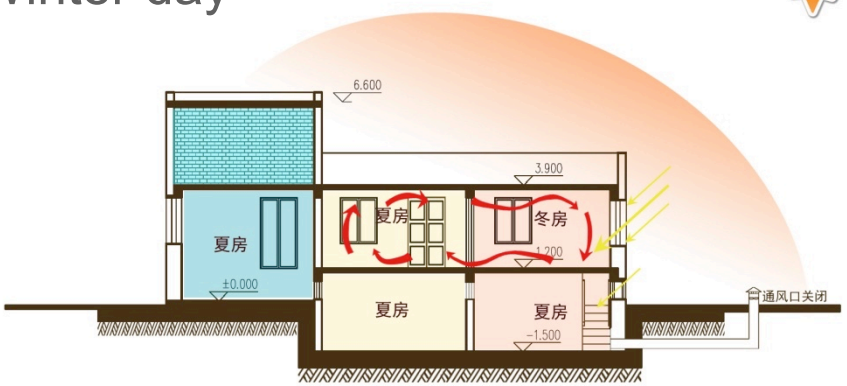


Thermal analysis

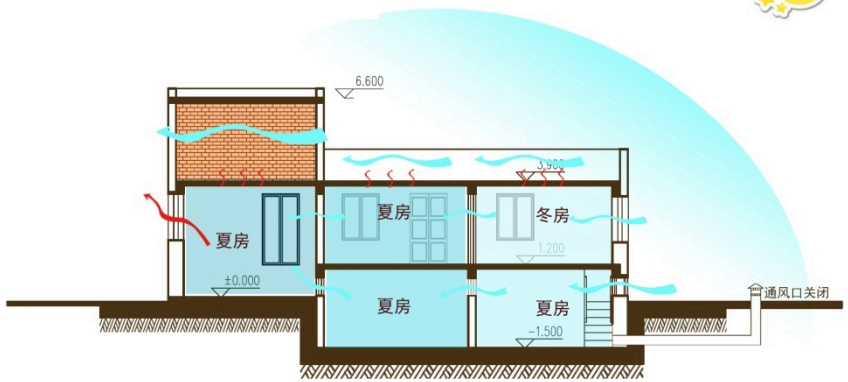
Summer day



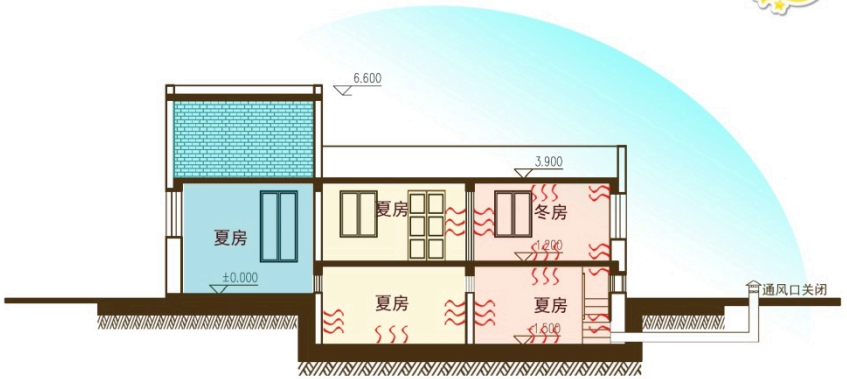
Winter day



Summer night

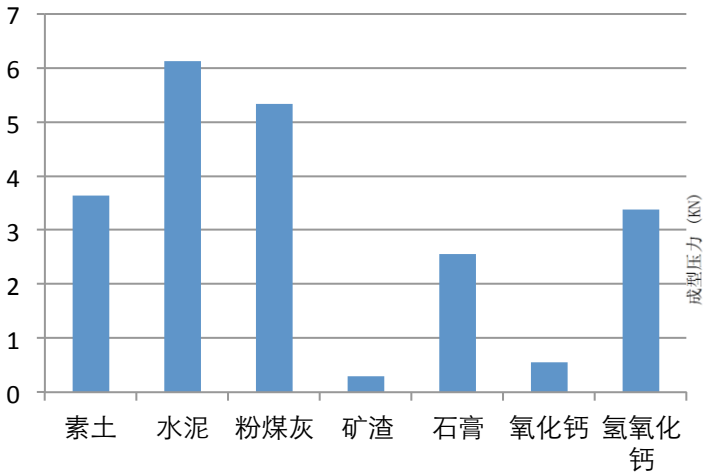


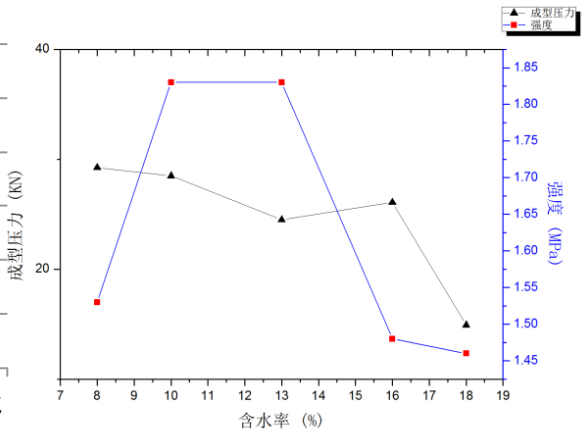
Winter night



introduced an adobe machine for better performance and saving labor cost.

The Earth Property Tests





- Before the adobe making procedure, we tested the mechanical properties of the earth with different combination of water ratio, supplement materials in our civil engineering materials lab, ensuring a good balance of cost and mechanical property for the adobes.

And here is the construction manual for local people.

一、施工流程

英买里村示范住区建筑施工由统一施工和居民自建两部分组成。

统一施工内容:

1）平整场地;
2）测量放线;
3）基槽开挖;
4）钢混框架搭建;
5）墙体基础砌筑。

居民自建内容:

6）土坯墙体砌筑;
7）楼板搭建;
8）屋顶搭建;
9）女儿墙砌筑;
10）晾房建造。

1）平整场地:
将场地平整，做到无障碍物。

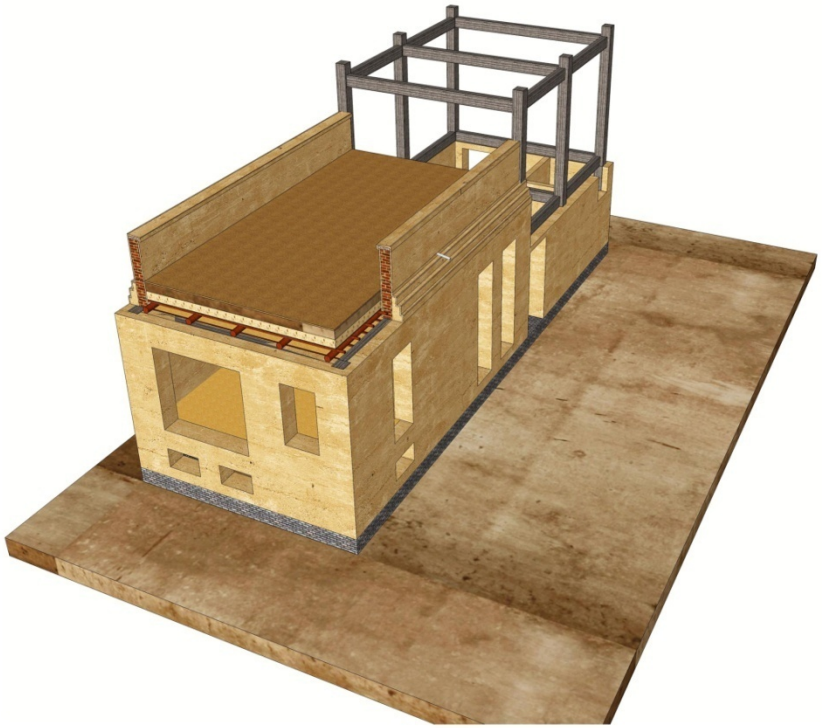
2）测量放线:
确定建筑外墙和内墙的位置。

3）基槽开挖:
基槽开挖深度不宜小于0.5米，基槽宽度约600-700mm。

4）钢筋混凝土框架搭建

5）墙基砌筑
先用300mm厚灰土、碎石或三合土填充处理地基。再用烧结砖,埋深不宜小于500mm，并高出室外地坪400mm。

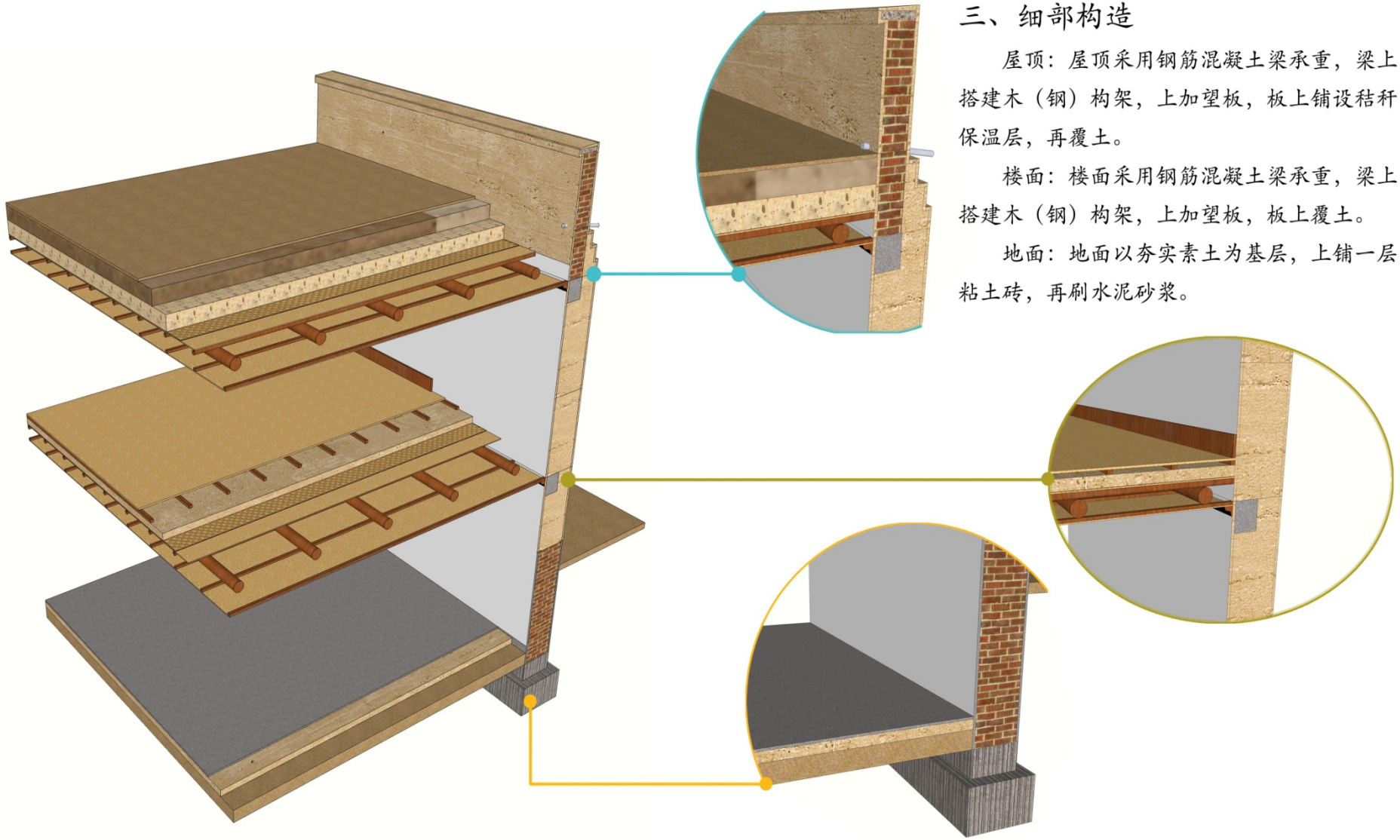
And here is the construction manual for local people.



9）女儿墙砌筑：
烧结砖砌筑而成，采用现浇钢筋混凝土构造柱和压顶加固，表面抹泥灰。

10）葡萄晾房搭建：
采用传统方法搭建，配合钢筋混凝土柱加固。

And here is the construction manual for local people.



三、细部构造

屋顶：屋顶采用钢筋混凝土梁承重，梁上搭建木（钢）构架，上加望板，板上铺设秸秆保温层，再覆土。

楼面：楼面采用钢筋混凝土梁承重，梁上搭建木（钢）构架，上加望板，板上覆土。

地面：地面以夯实素土为基层，上铺一层粘土砖，再刷水泥砂浆。

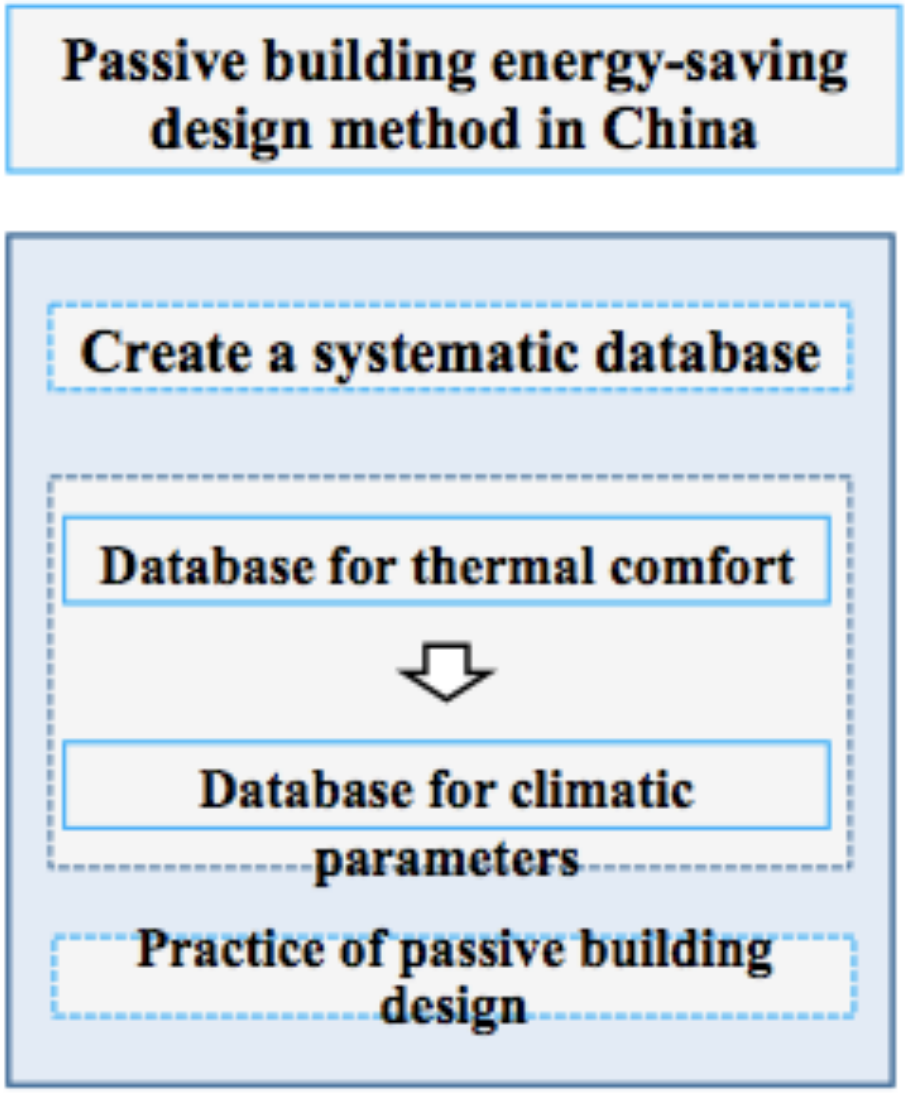
Conclusions

- 1. Chinese people prefer passive designs that are connect to natural environment, they are also comfortable at wider temperature range than that specified by comfort standard, which shall be considered in designing buildings more efficiently;
- 2. Buildings shall be deigned with local climate, means shall be made to minimize heating and cooling by passive designs that adapt to local climate;
- 3. Bioclimatic design is essential for building energy efficiency in China under current economic, climate and comfort requirements in China;
- 4. In developing rural area, maintaining valuable traditional passive design methods while introducing modern building technology to improve built environment quality are important to build low cost houses that meet safety comfort requirements.

Next steps

- We will continue our study on passive design, aiming to establish a comprehensive passive design method for China, and to develop a database for building energy efficiency designs.

- Anyone who is interested in passive design in China are welcomed to participate in our future studies.



Green Center in XUAT

Thanks for your attention ！