Hybrid solar heating R&D in China

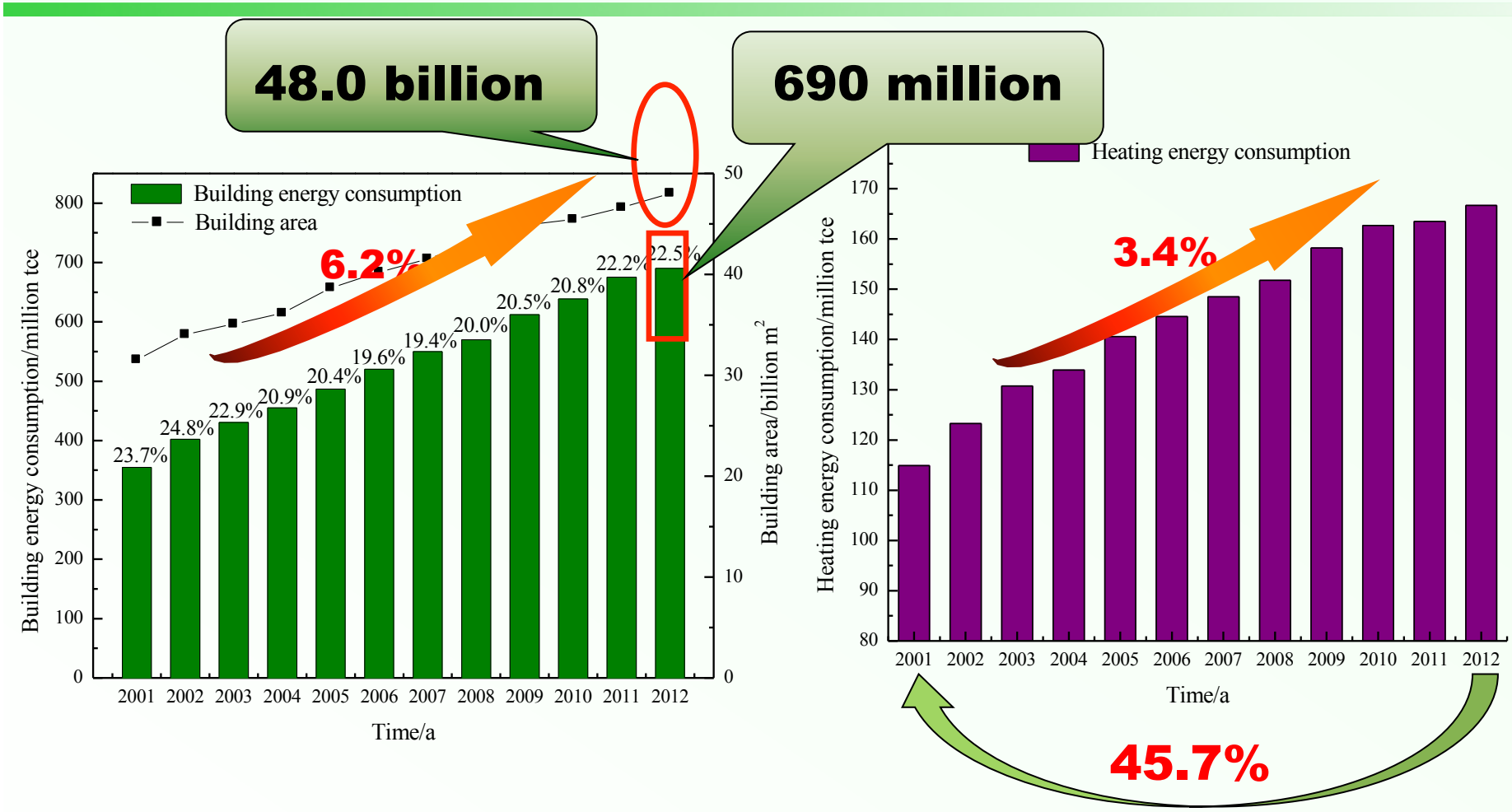
Prof. Liu Yanfeng

Contents

1. Energy consumption and renewable energy status of China
2. Advantages of solar heating in northwest China
3. Passive and active solar heating system
4. Sleeping Thermal Environment for Solar Heating in Northwest China
5. Demonstrative project

1.Energy consumption and renewable energy status of China

Energy consumption status of China



- The building energy consumption and building area are about 690 million tce and 48.0 billion in 2012, respectively.
- The building energy consumption had grown by an average of 6.2% per year from 2001 to 2012.
- Compared with 2001, the heating energy consumption of 2012 had increased by 45.7%.

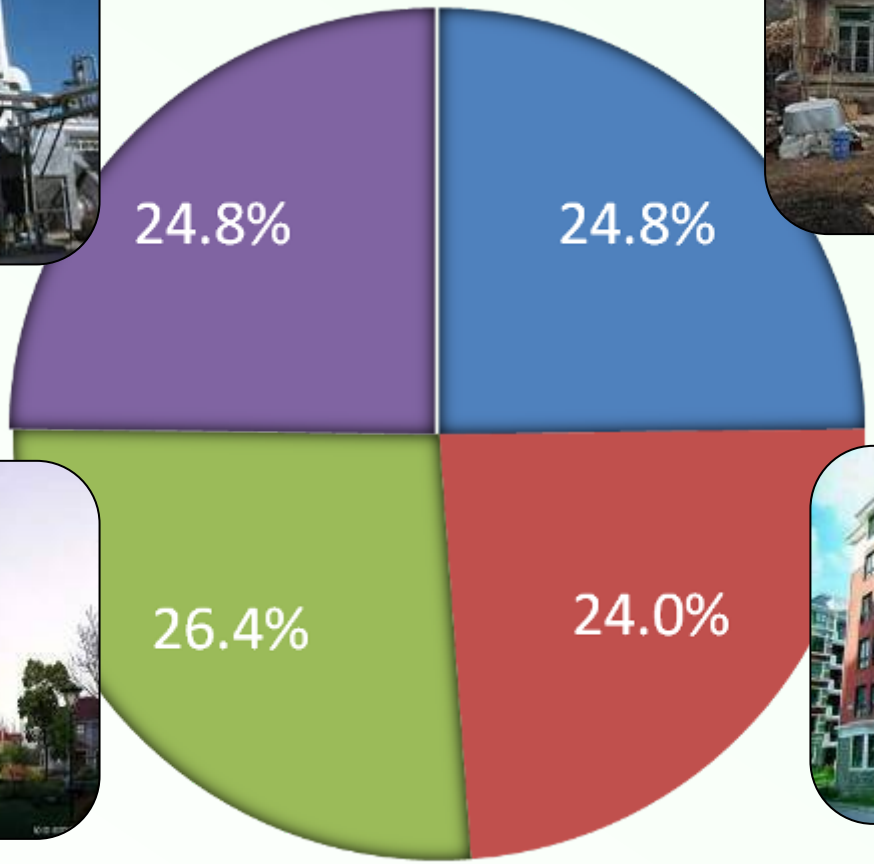
Energy consumption status of China

North Town heating

Rural residential buildings

Public buildings

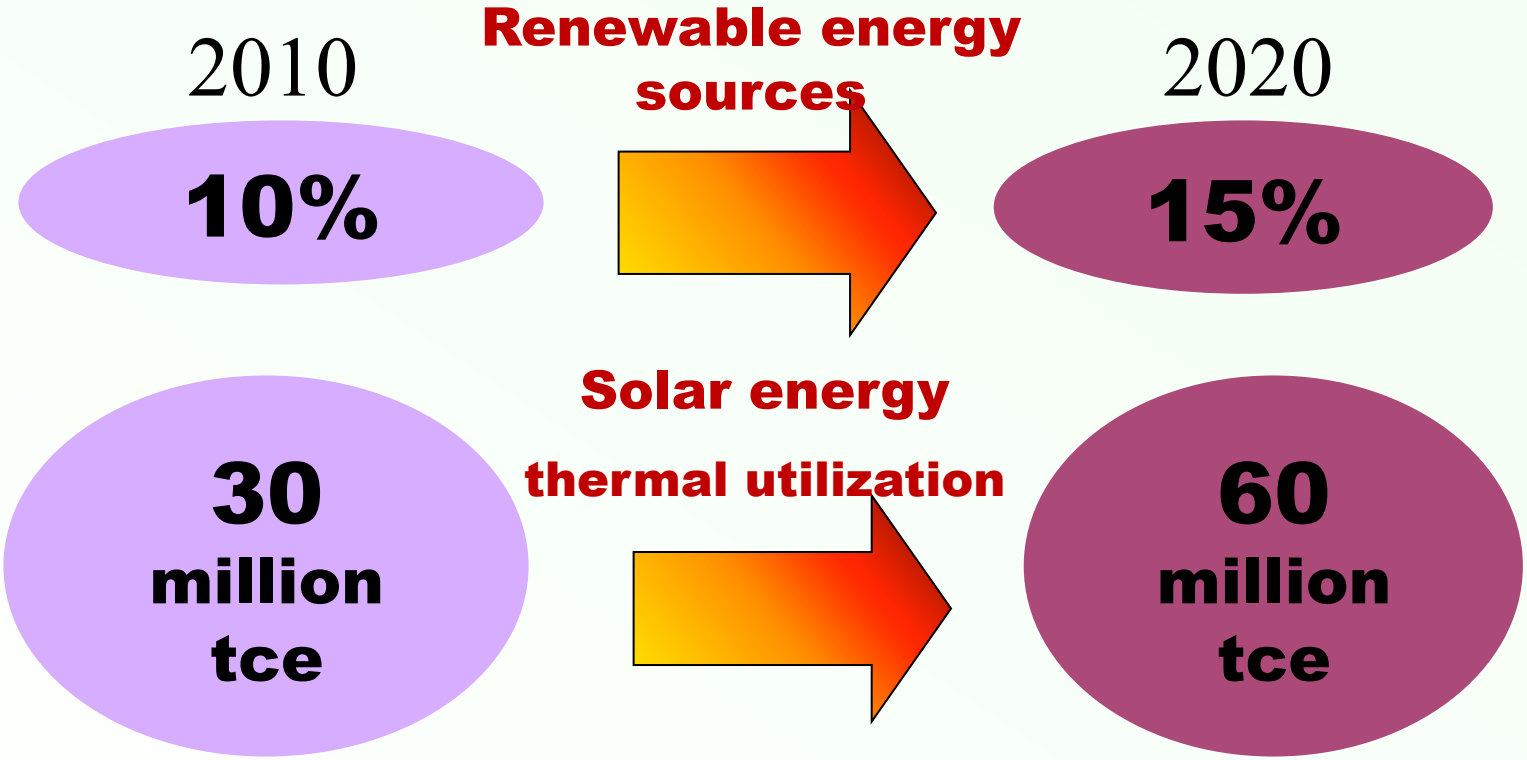
Town residential buildings



l The town heating energy consumption in the proportion of the total energy consumption is about 24.8%.

Development plan of renewable energy

l "The renewable energy sources medium and long-term development plan of China"



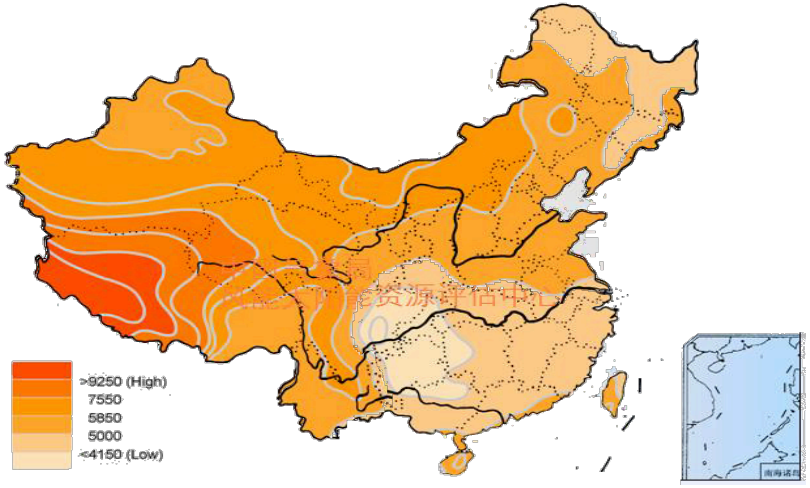
l The proportion of energy utilization of renewable energy sources will increase from 10% to 20%.

l The thermal utilization of solar energy will increase from 30 to 60 million tce.

2. Advantages of solar heating in northwest China

Solar heating are suit for Northwest China

Heating region



Solar energy resource

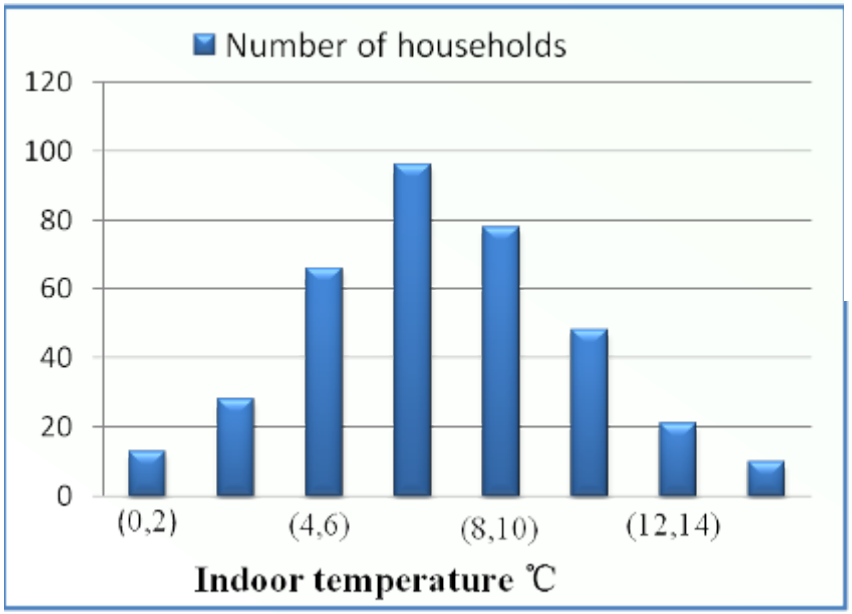
Northwest of China

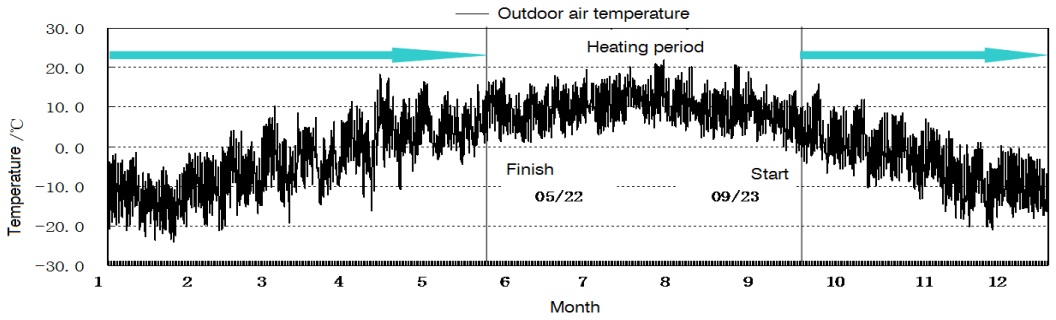
High overlap

Indoor thermal environment of Northwest China



Cold and severe cold regions

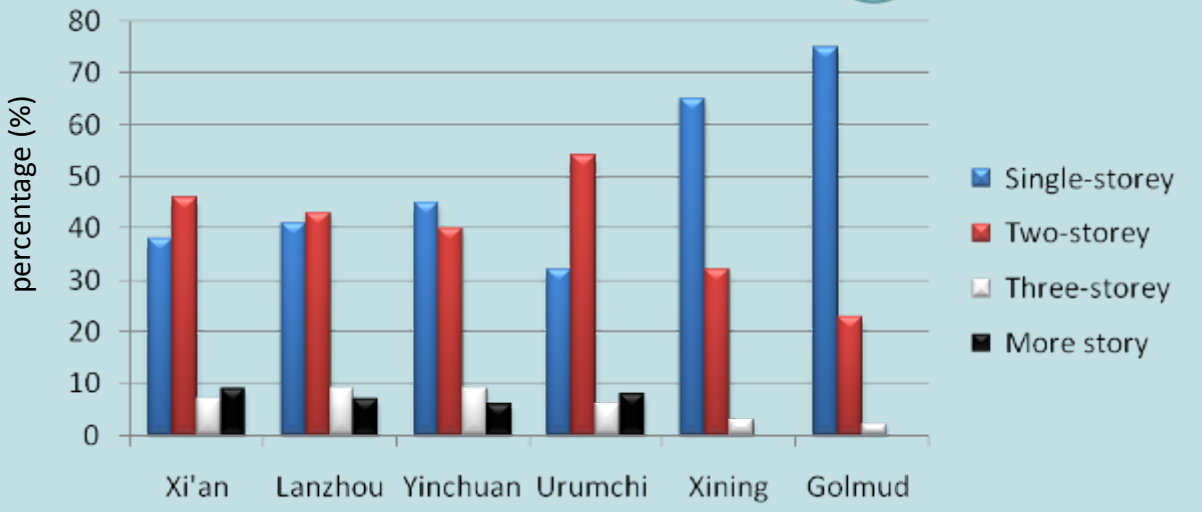




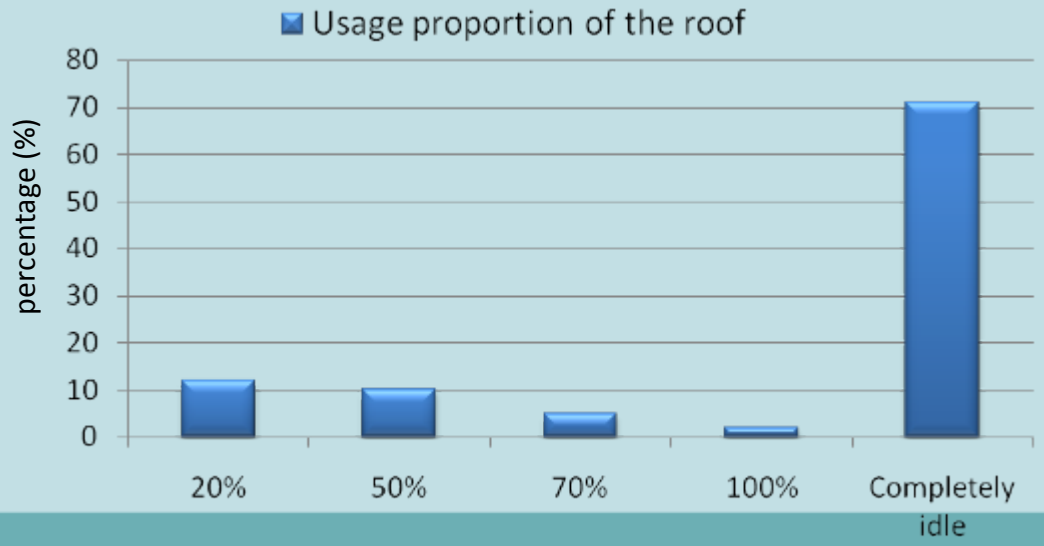
Long heating period

- Poor indoor thermal environment
- No heating systems in rural area
- Room heating depend on stove and Kang.

Advantages of solar heating in Northwest China



p Most buildings are single or two-storey.



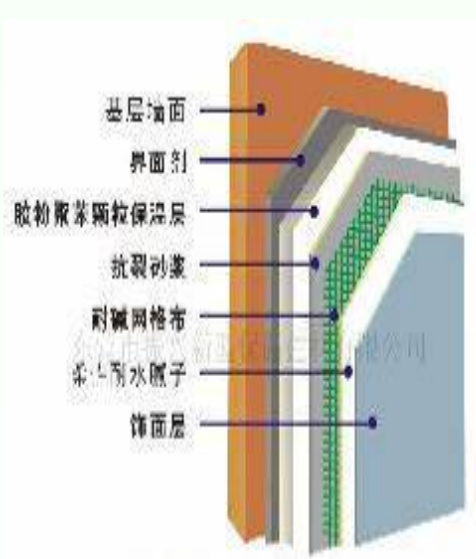
p Most roofs are idle for solar collection.

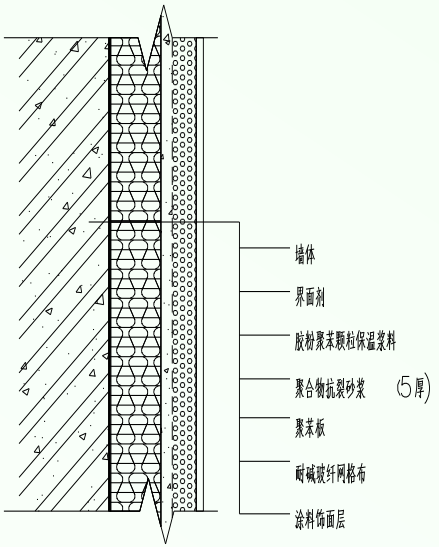
3. Passive and active solar heating

Efficient building envelope heat preservation

Thermal parameter of the external envelope

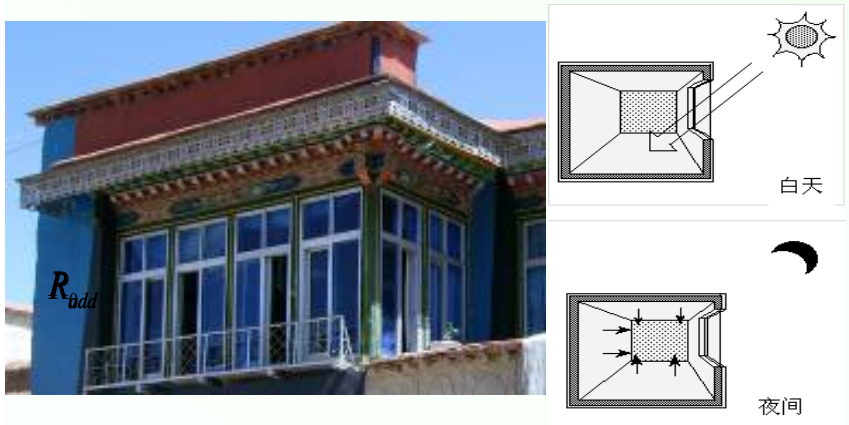
City	External window				Exterior wall	roof	Ground		Door	Balcony door
	West and east		North				Surrounding ground	Central ground		
	Window-wall ratio	Heat transfer coefficient	Window-wall ratio	Heat transfer coefficient	Heat transfer coefficient					
Lhasa	≤0.25	≤3.30	≤0.20	≤3.30	≤0.90	≤0.70	≤0.52	≤0.30	≤2.70	≤1.70
Damxung	≤0.20	≤2.60	≤0.20	≤2.60	≤0.65	≤0.60	≤0.60	≤0.30	≤1.50	≤1.35
Nyingchi	≤0.25	≤3.30	≤0.20	≤3.30	≤0.80	≤0.70	≤0.52	≤0.30	≤2.70	≤1.70
Lhatse	≤0.25	≤3.30	≤0.20	≤3.30	≤0.90	≤0.80	≤0.52	≤0.30	≤2.70	≤1.70
Gyangze	≤0.25	≤3.30	≤0.20	≤3.30	≤0.80	≤0.70	≤0.52	≤0.30	≤2.00	≤1.70
Chamdo	≤0.25	≤2.60	≤0.20	≤2.60	≤0.80	≤0.70	≤0.52	≤0.30	≤1.50	≤1.70
Tsonag	≤0.20	≤3.30	≤0.20	≤3.30	≤0.65	≤0.65	≤0.52	≤0.30	≤1.50	≤1.70
Nagchu	≤0.20	≤2.60	≤0.20	≤2.60	≤0.65	≤0.60	≤0.30	≤0.30	≤1.50	≤1.35
Amdo	≤0.20	≤2.60	≤0.20	≤2.60	≤0.60	≤0.60	≤0.30	≤0.30	≤1.50	≤1.35
Gerze	≤0.20	≤2.60	≤0.20	≤2.60	≤0.60	≤0.60	≤0.30	≤0.30	≤1.50	≤1.35



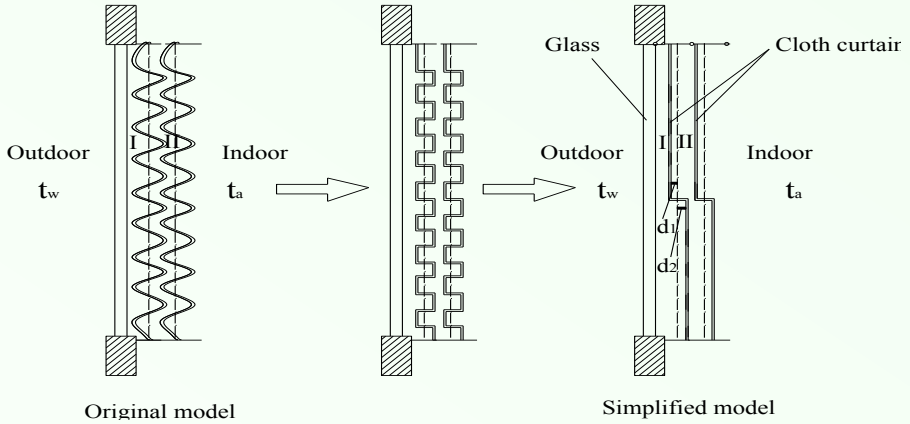


Passive solar heating

Direct benefit window



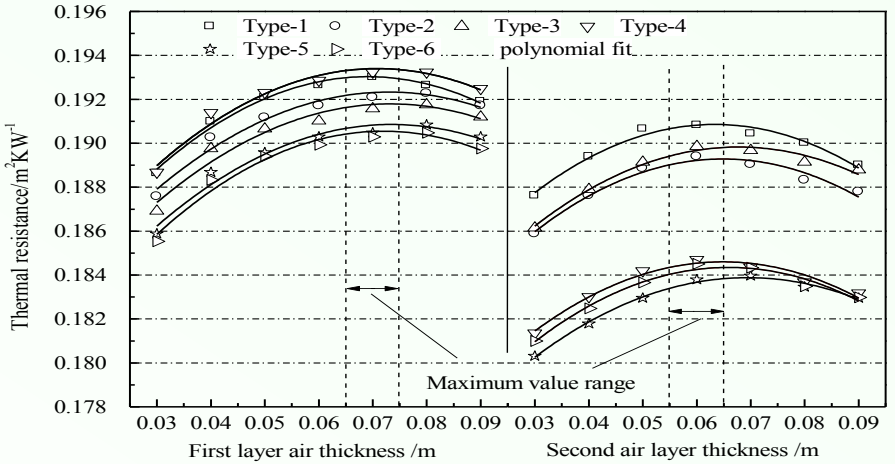
Direct benefit window



Simplified model of the curtain

Types	R_0 ($m^2 \cdot K \cdot W^{-1}$)	Single cotton curtain			Single linen curtain		
		R_{add} ($m^2 \cdot K \cdot W^{-1}$)	R ($m^2 \cdot K \cdot W^{-1}$)	P/%	R_{add}/ ($m^2 \cdot K \cdot W^{-1}$)	R/ ($m^2 \cdot K \cdot W^{-1}$)	p/%
Type 1	0.156	0.244	0.400	61.0	0.192	0.348	55.2
Type 2	0.270	0.227	0.497	45.7	0.181	0.451	40.1
Type 3	0.333	0.224	0.557	40.2	0.173	0.506	34.2
Type 4	0.213	0.232	0.445	52.1	0.187	0.400	46.8
Type 5	0.385	0.209	0.594	35.2	0.167	0.552	30.3
Type 6	0.435	0.209	0.644	32.5	0.162	0.597	27.1

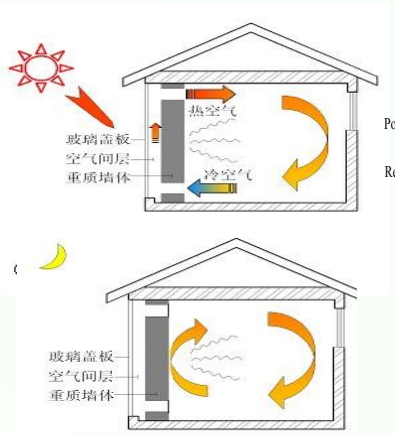
Thermal resistance of the curtain



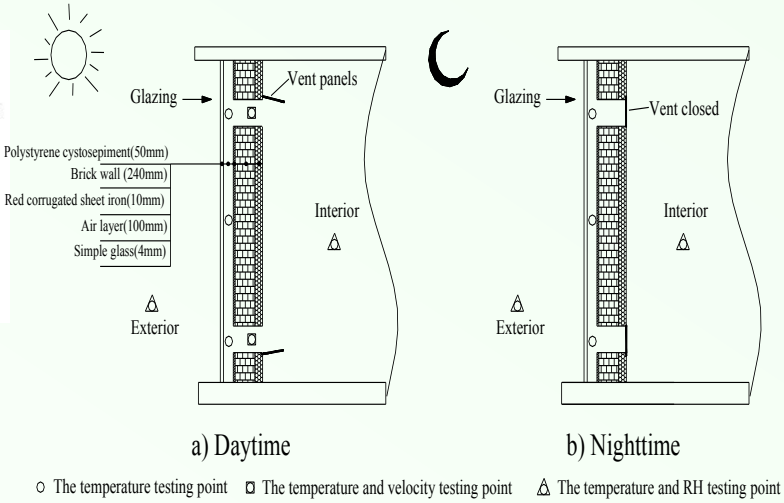
The optimal thickness air layer thickness

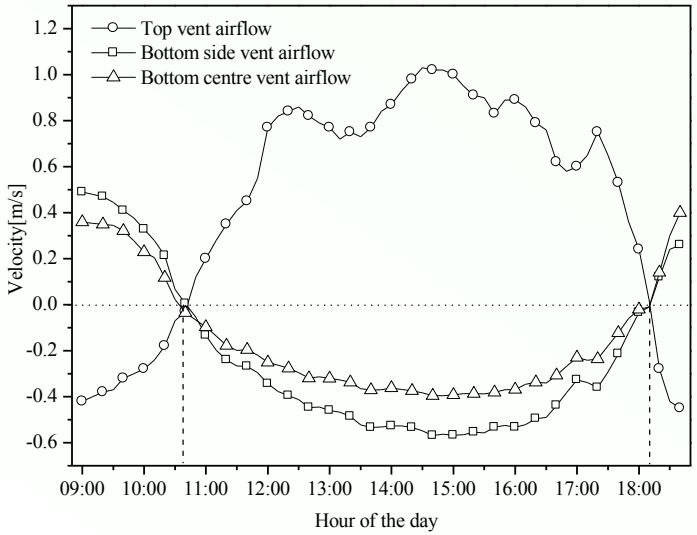
Passive solar heating technology

Trombe wall

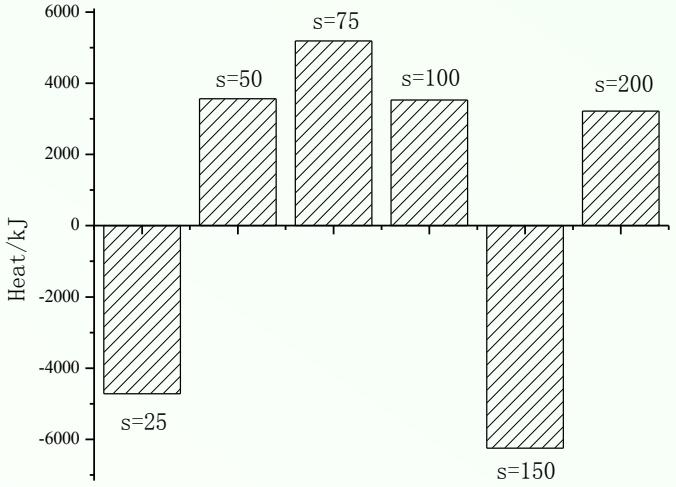


Trombe wall





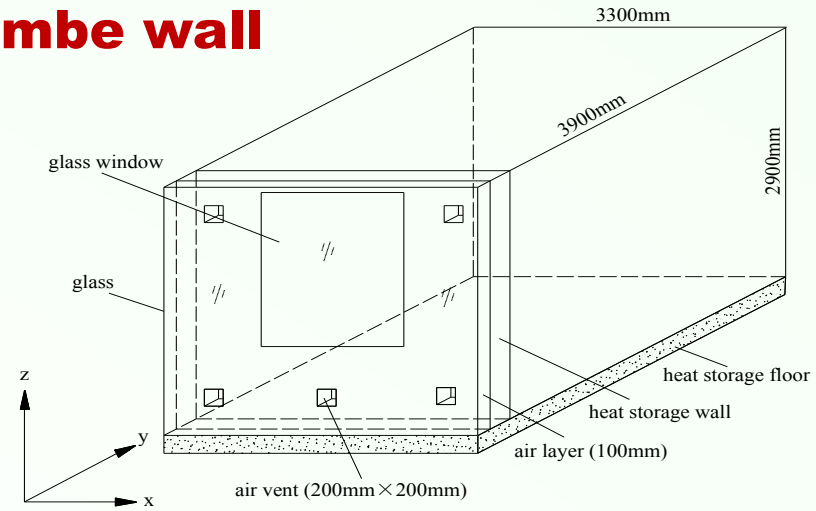
The velocity of trombe wall air vents



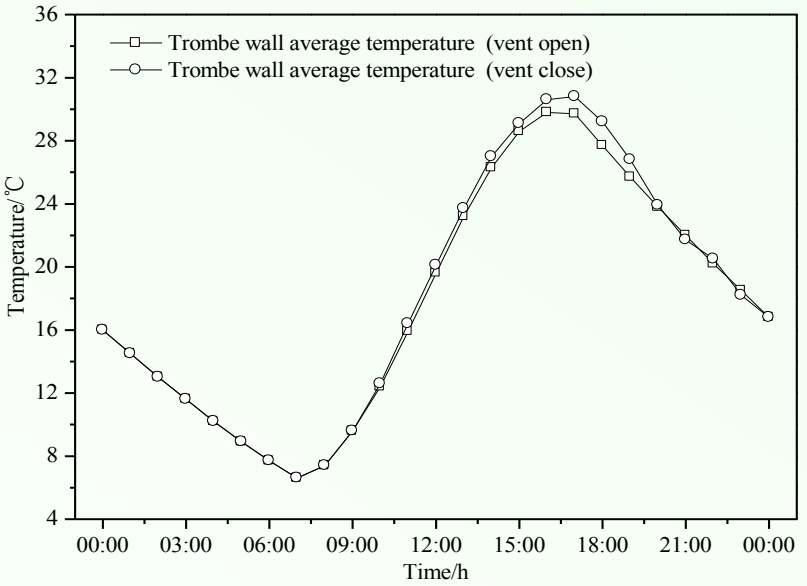
Optimal air layer thickness

Passive solar heating technology

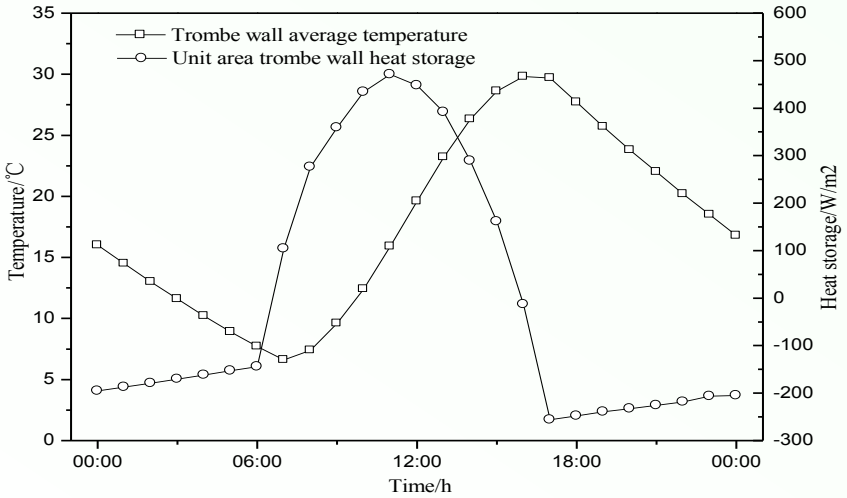
Trombe wall



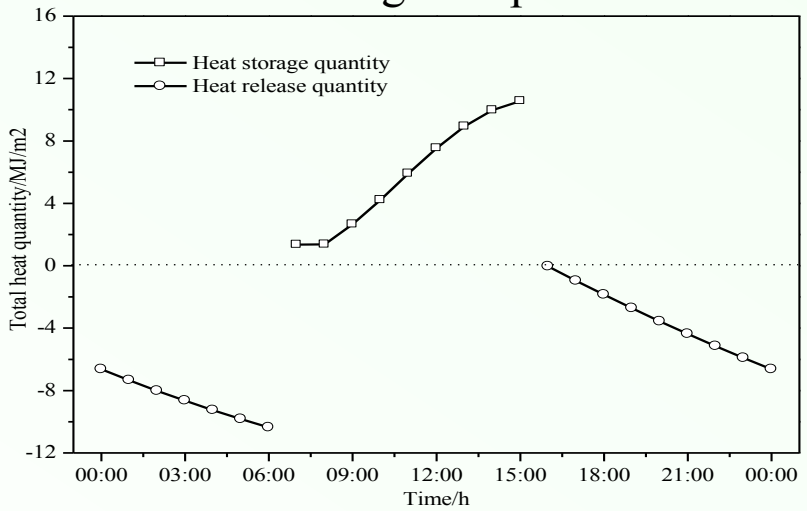
Simulation model



Average temperature

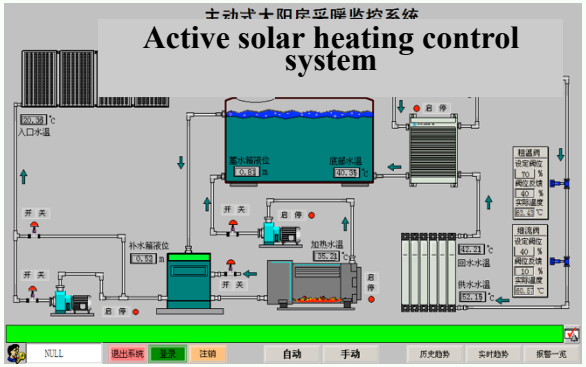


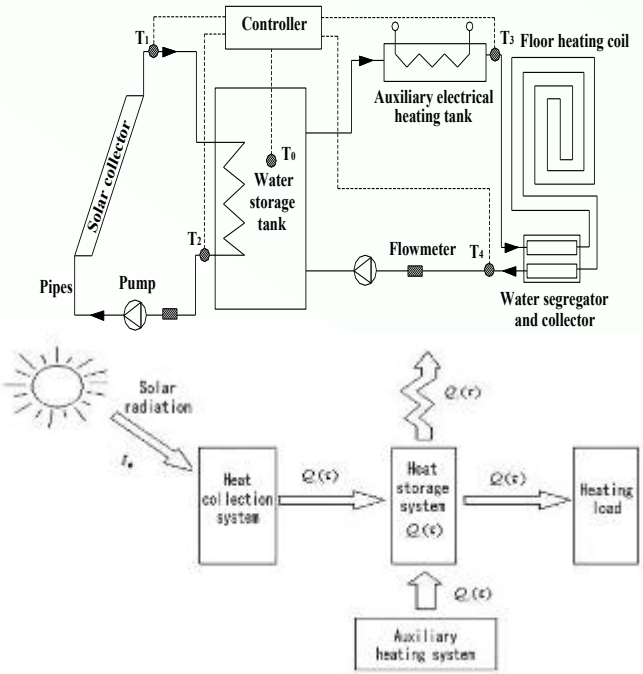
Unit-volume heat storage



Total heat storage

Active solar heating system

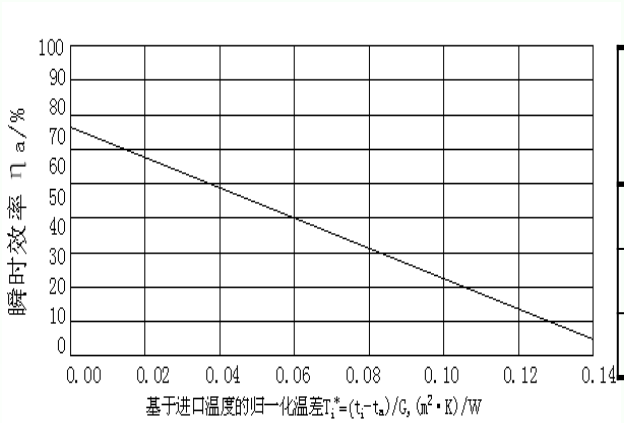




Solar heating model

Solar collector

Solar Collectors



heat collecting efficiency

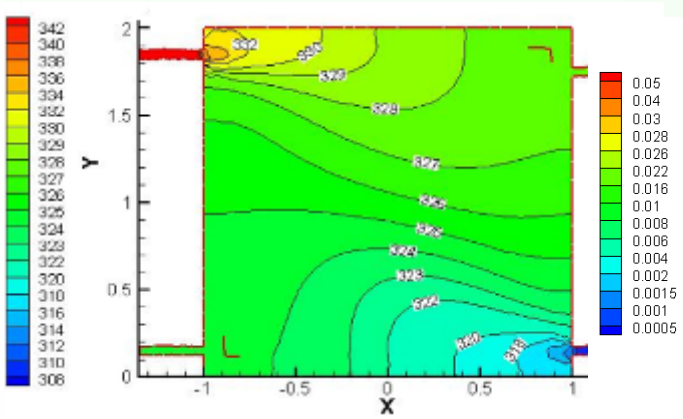
Conditions	Energy saving 50%		
	2F	4F	6F
Lasas	132%	73%	50%
Xi'an	45%	25%	17%
Xi'ning	32%	17%	11%

solar fraction

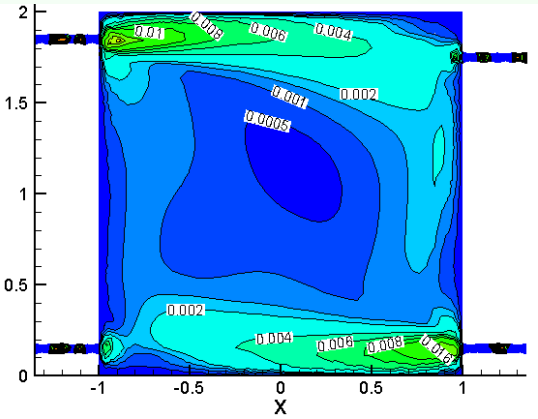
Active solar heating system

I heat storage

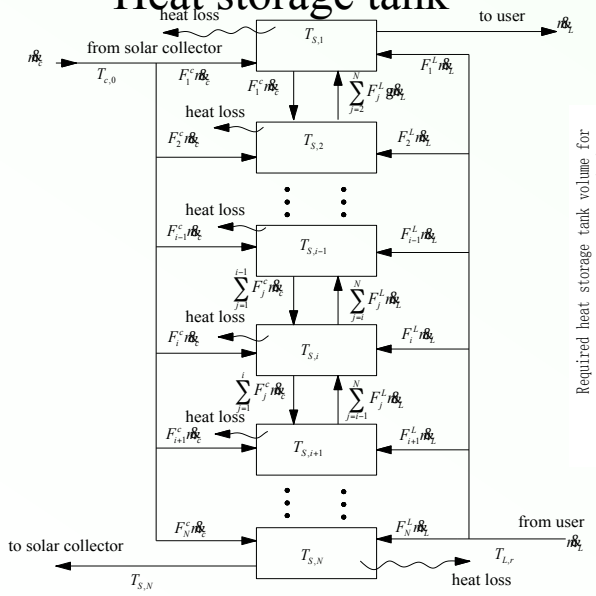
Heat storage tank



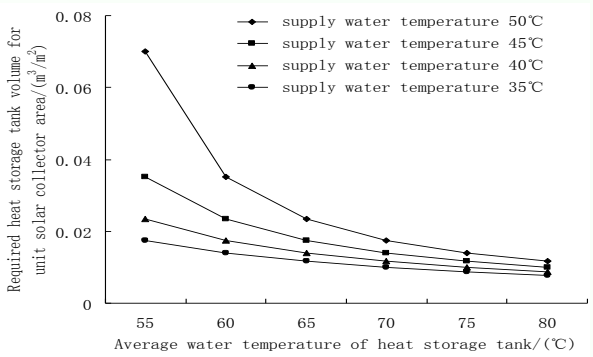
Temperature stratification of heat storage tank



Flow velocity of heat storage tank



The nodal model of heat storage tank



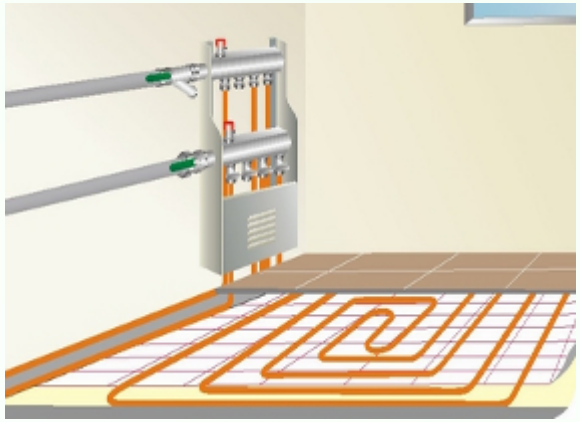
Requested volume of heat storage tank

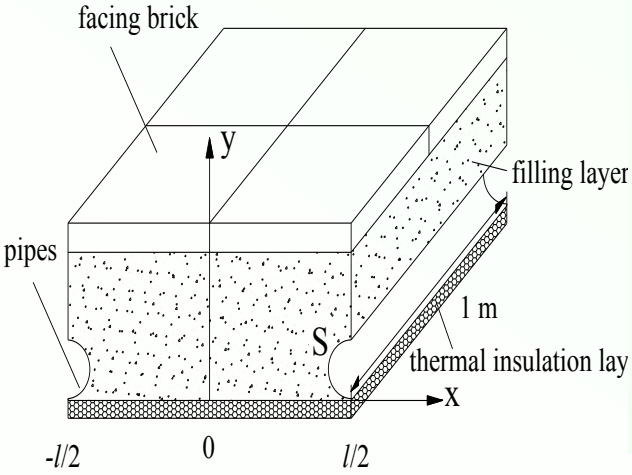
Recommended values of heat storage volume (m^3/m^2)

Cities	Maximum	Minimum	Recommendation
Lhasa	0.3	0.03	0.1～0.15
Yinchuan	0.15	0.02	0.05～0.08
Xining	0.11	0.02	0.04～0.06
Xi'an	0.07	0.01	0.03～0.04

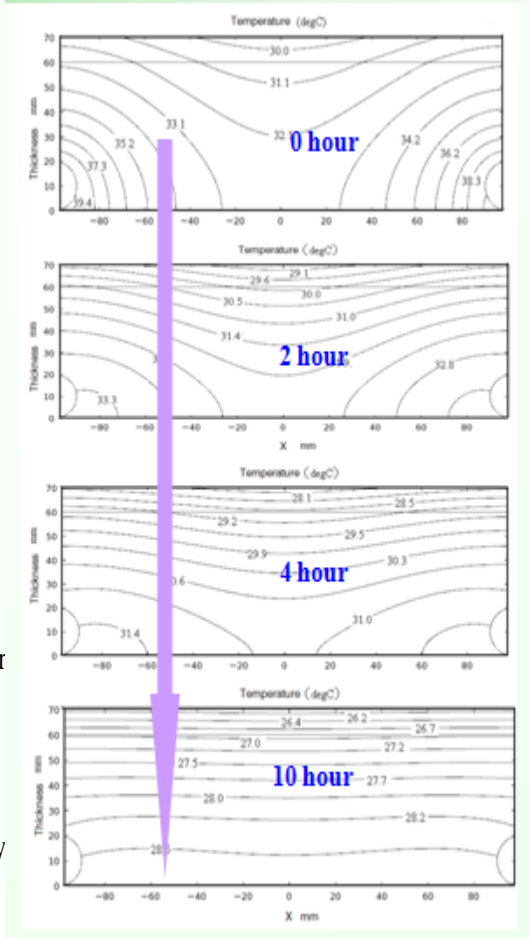
Active solar heating system

Floor radiant coil heat release

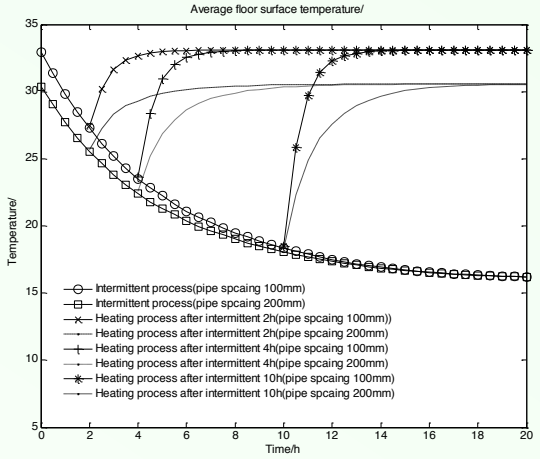


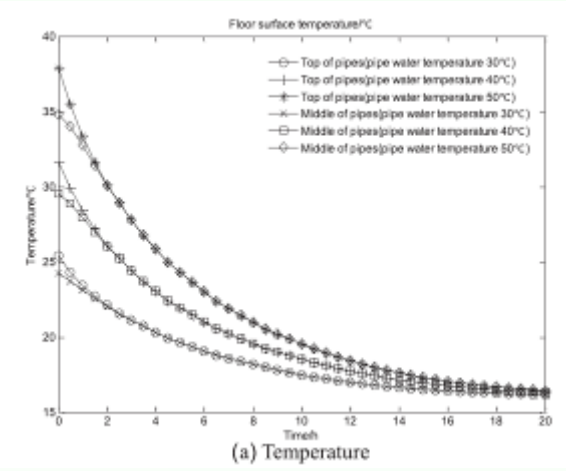


Floor radiant coil model



Temperature distribution



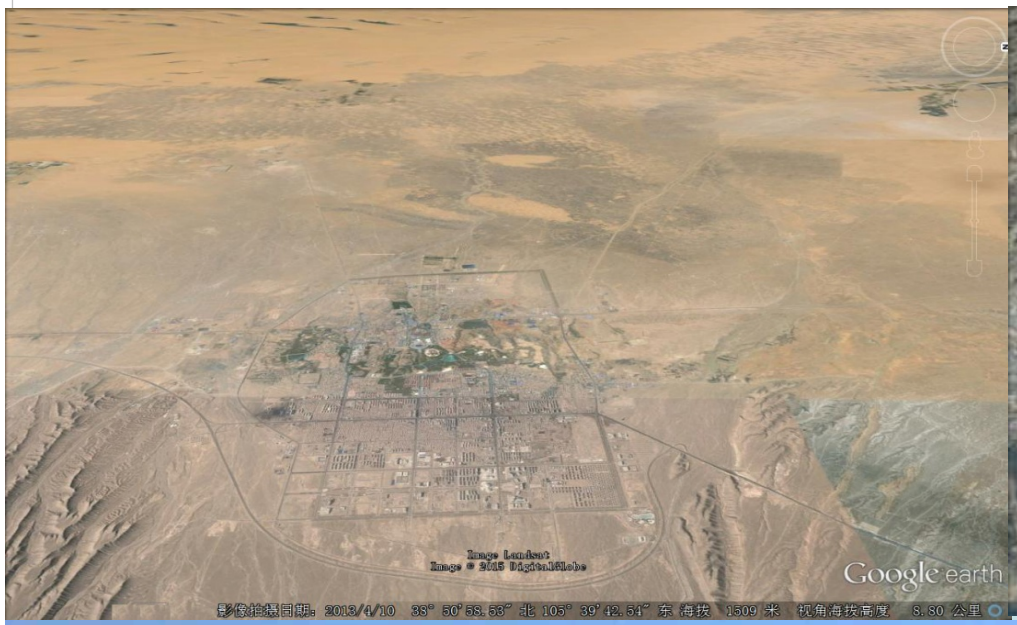


(a) Temperature

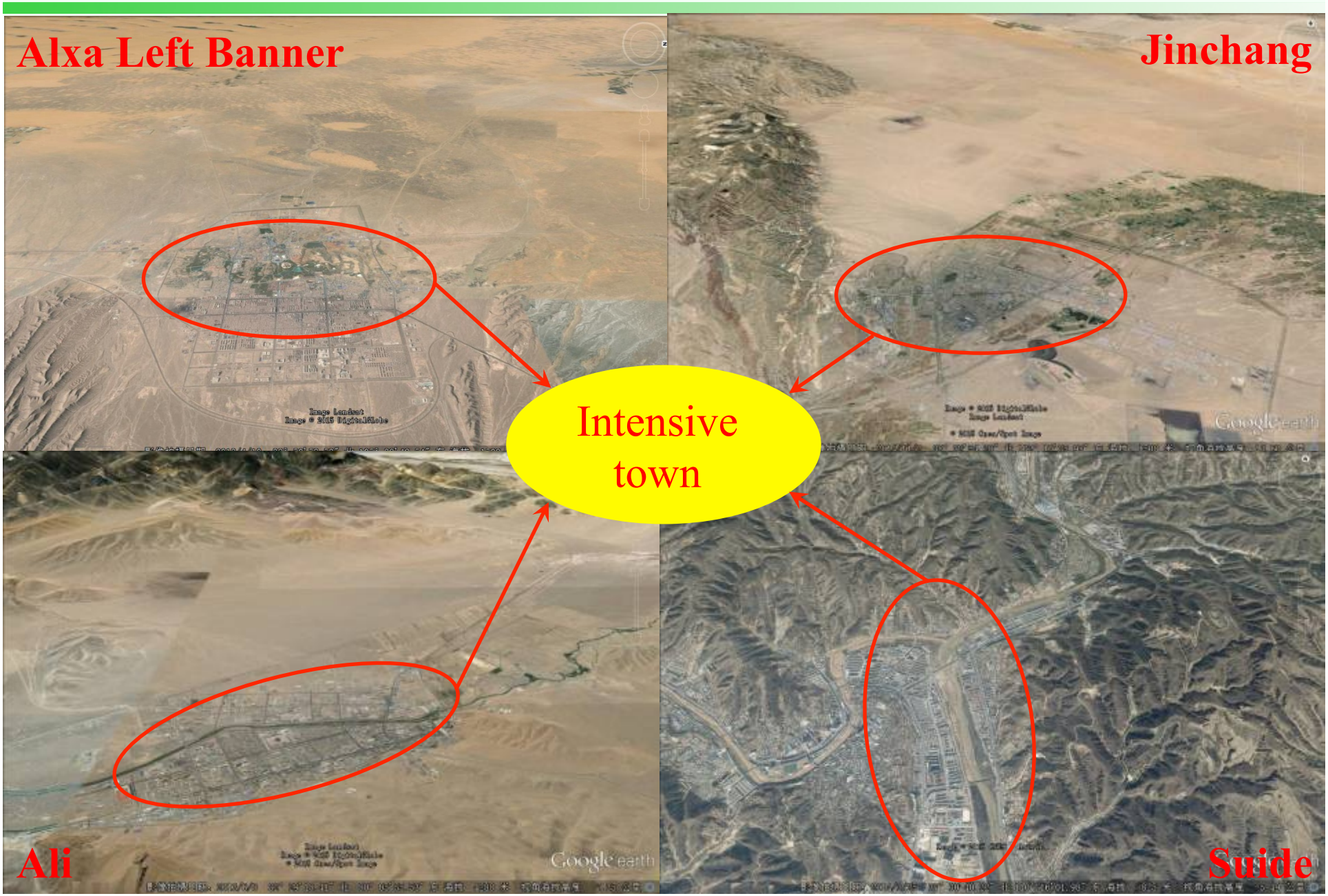
Average surface temperatures

3. “Oasis” city provide conditions for solar central heating

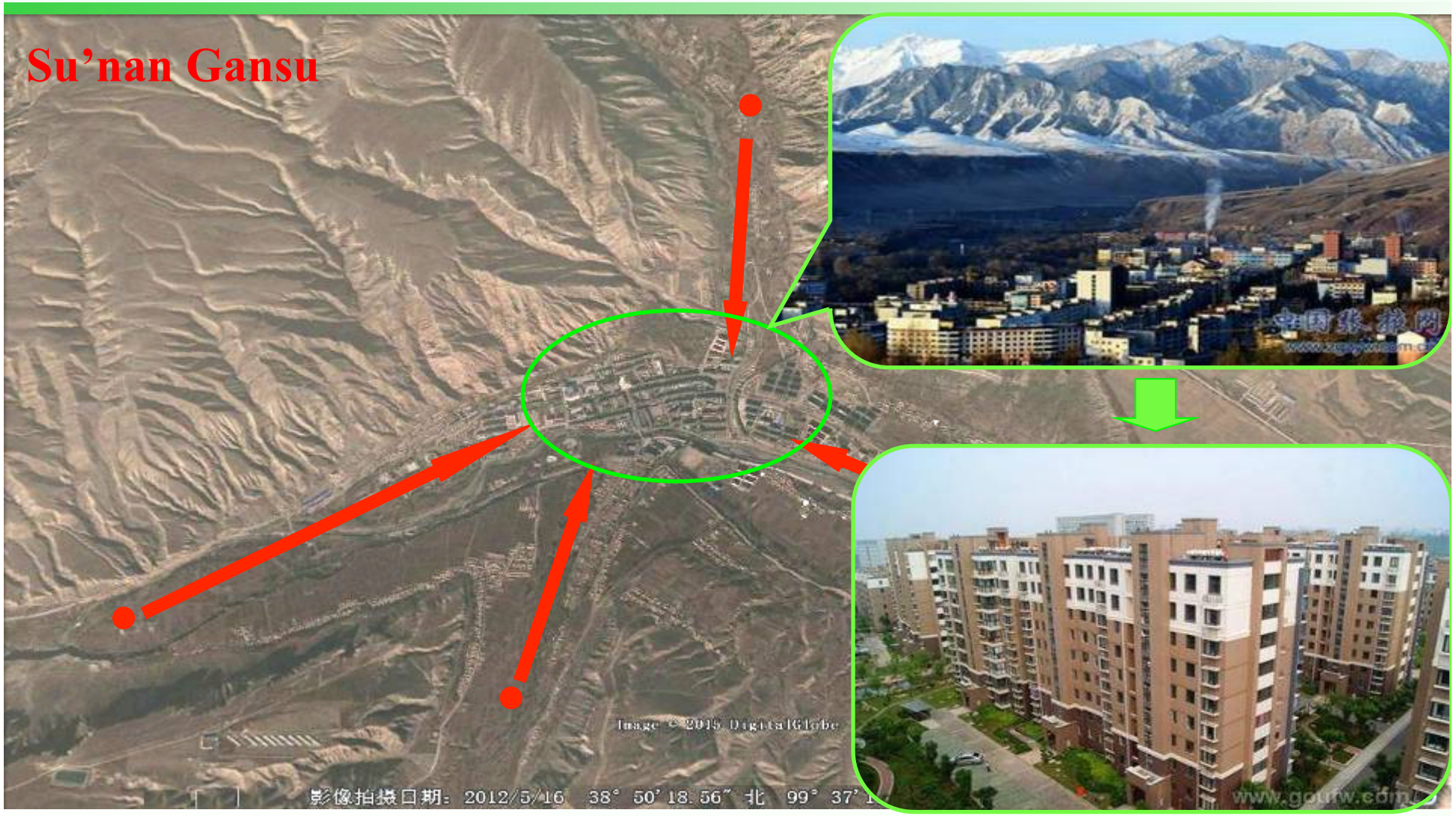
There are enough space for solar collection



“Oasis” city in Northwest China



The fast-developing “Oasis” city



Urban expansion, population concentration, Volume rate increase

The other “Oasis” cities

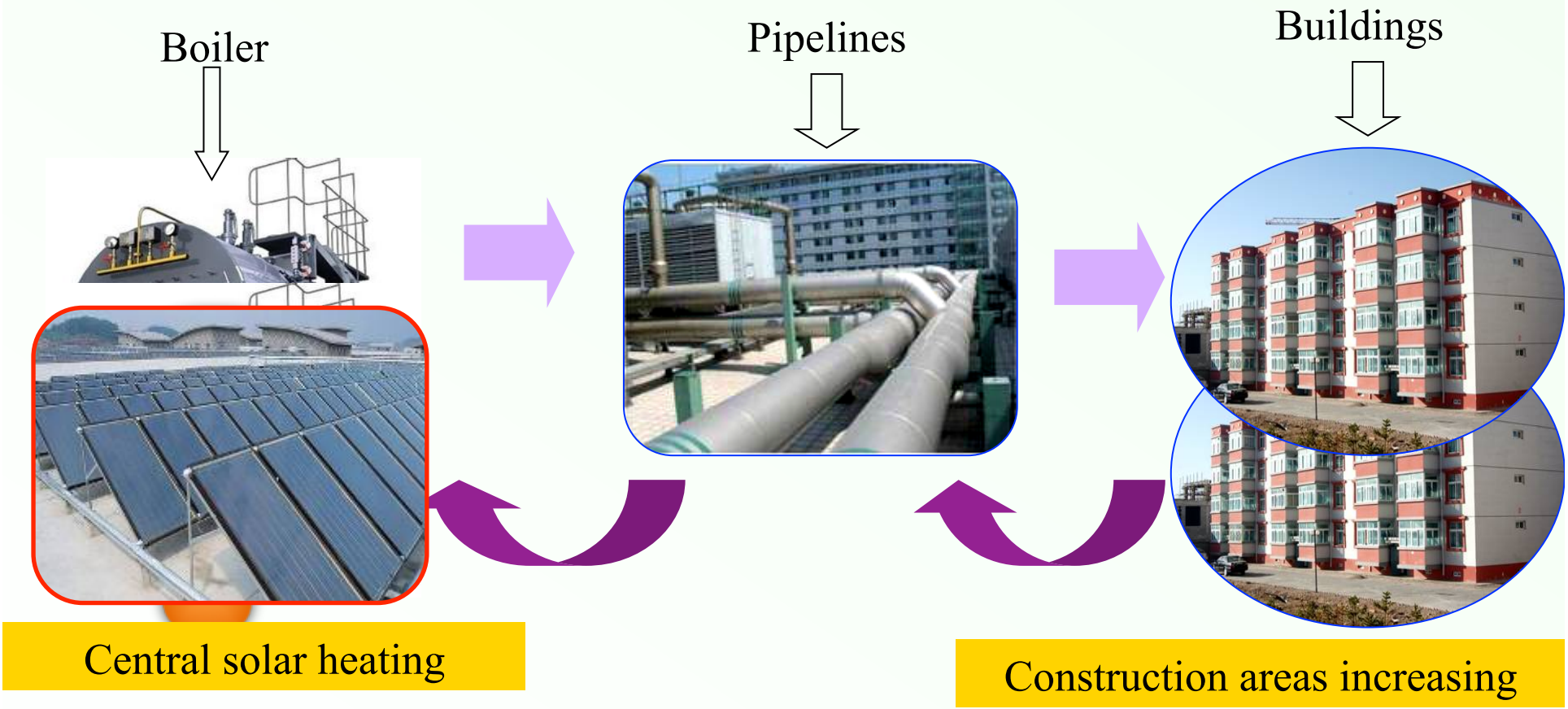
Present status of solar energy utilization in China

Solar hot water

Solar photovoltaic power generation

Solar energy heating

Central solar heating and original heat source



The key scientific problems

l Match method between solar thermal system and existing heating system a s well as calculation method of feasible system parameter.

l Design and calculation method for thermal storage hydraulic system.

lBased on the specified heat demand and existing boiler, the matching relati on of heat collection and storage capacity ? reasonable
adjustment and control technology ?

l The demonstration project that integrates with research results .

4. Sleeping Thermal Environment for Solar Heating in Northwest China

Current situation

Building type	Occupied feature
Office	Layoff at night (working days) Layoff all-day (holidays)
School	Layoff at night (school days) Layoff all-day (winter vacation)
Residence	Bedroom—— occupied during night normally

Investigations of residential building

Usage rate of rural residential building according to human behavior

Room	Bedroom	Sitting room	Outdoor	Kitchen & Bathroom
Percentage of time (%)	**41.4**	**27.9**	**23.6**	**7.0**
Average hours per day (h)	**9.9**	**6.7**	**5.7**	**1.7**

Time parting and room-function distinction is suitable for

Heating load allocation of rural residential building

Simple rural dwelling

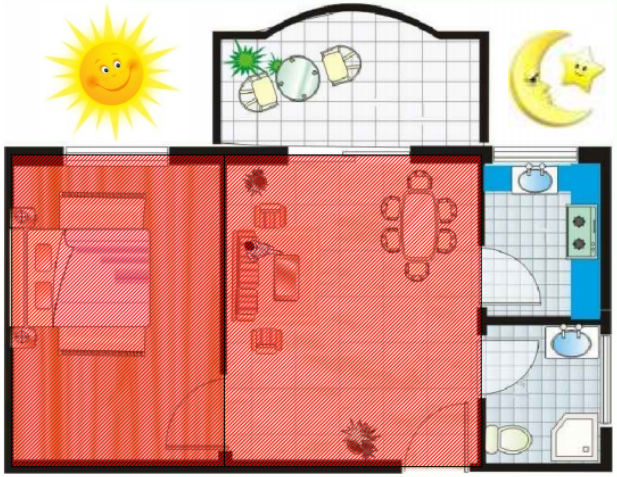
Thermal insulation

Passive solar house

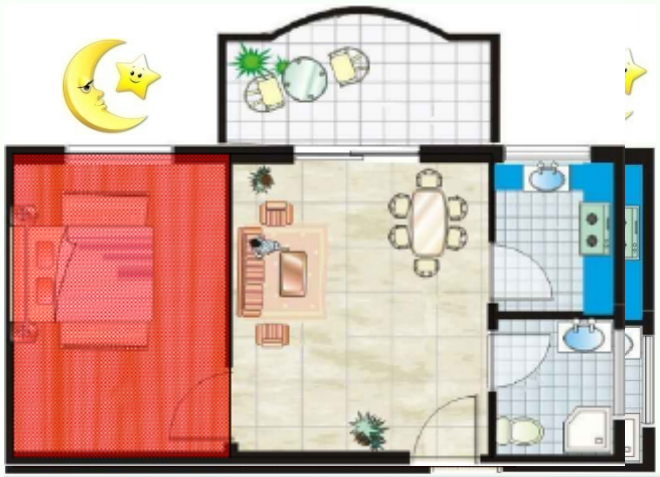
Time parting & Local heating

Active solar system

HL 100% → HL 50% → HL 35% → HL 25%



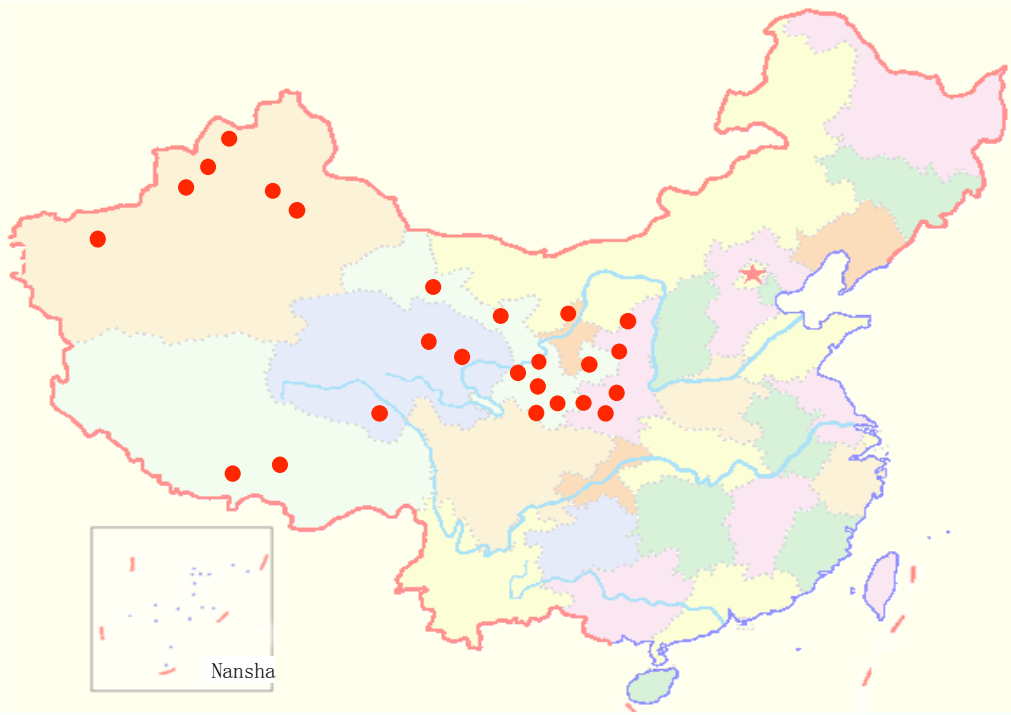
Day and night the whole house

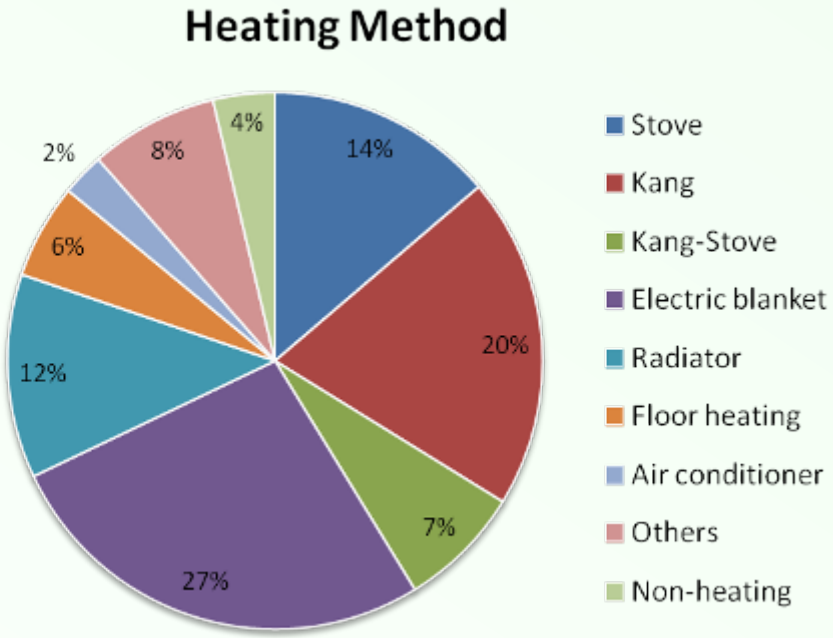


Night time bedroom

Night time bedroom & bed climate

Survey of sleeping environment





More than 400 dwellings in 22 cities in Northwest China

Solar heating system could only used for meeting the thermal demand of local site (e.g. the bed climate) to reduce energy consumption.

Chinese Kang
Kang combine Stove
Electric blanket

→ **54%**

Essential elements

Solar heating system design based on human behavior for maximum utilization and thermal comfort assurance

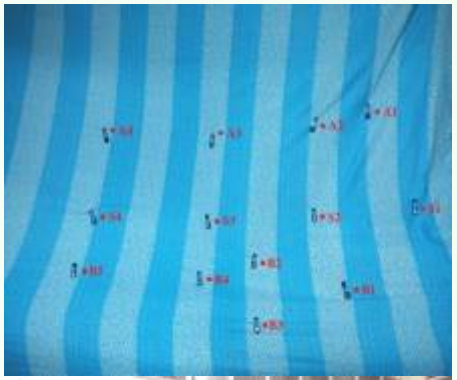
Essential but unknown elements

- Indoor thermal environment design parameters for night time
- Bed climate demand during night
- Match relation between the above two thermal environment

Lab Study








- Filling out questionnaires
- Preparing for measurements

Morning investigation

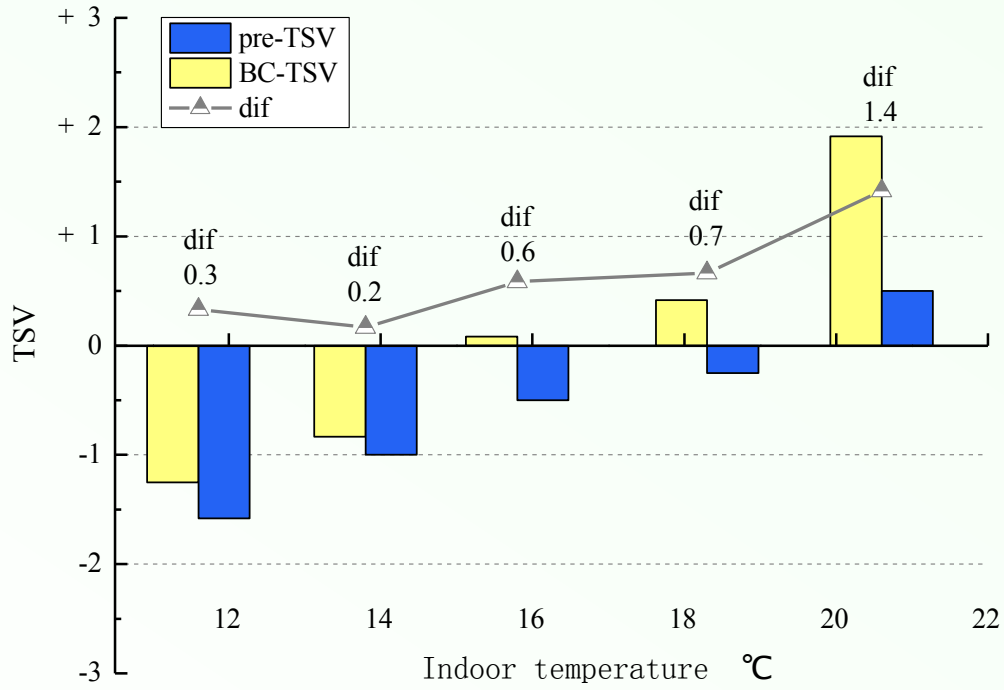
22:00 — Subjects arrived at the climate chamber

22:30

23:00 — Subjects fall asleep

7:00

Difference of thermal sensation between sleeping and waking state



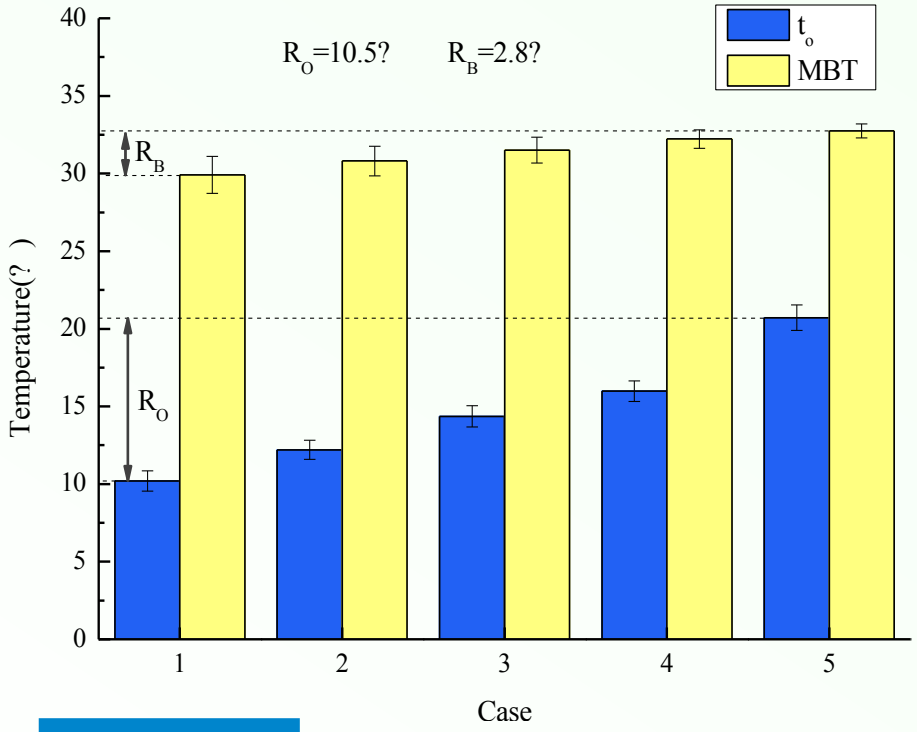
Findings

- TSV during sleep higher than awake
- Enlarged disparity as operative temperature increases

Reasons

- Energy expenditure is reduced due to less physical activity.
- **Bed and coverings create a warm microclimate, i.e., bed climate.**

Temperature of Indoor environment and bed climate



Findings

- Warm bed climate with temperature above 30.0℃
- More stable temperature in bed climate

Comments

- MBT refers to the mean bed temperature around the upper body of a supine person.
  - The thermal resistance of the bed system is 3.73clo (Lin Z.P., Deng S.M. 2008).
    - **Human body is more susceptible to bed climate.**

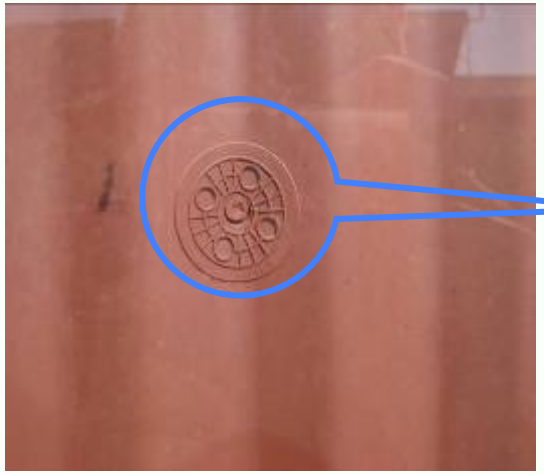
Field Study

5.Demonstrative project

Geographic location

Design concepts

Ø Trombe wall



Design concepts

Ø Sunspace

Design concepts

Ø Active system equipments

Solar collector

Electrical heating water tank

Heat storage tank

Pipes

Controller

Water segregator and collector


1:12 000 000

Thank you for your attention!