2016 Integration of District Heating in a Sustainable Energy System

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– Technologies, Markets and Policies

—技术、市场与政策

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Sustainable technical roadmap of Zero-coal low energy region in Zhangjiakou, Hebei Province, China

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IEE, CAS

BEIJING OCT. /18/2016

Content


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Background

Objective of renewable energy development in Zhangjiakou City

- **Renewable energy use ratio:**
  - **By 2020, RE 30%, 2030 50%. both the economic and social sectors of the city.**
  - **By 2020, electricity consumption 55%, city transportation 100%, urban residents' livelihood power consumption 40%, commercial & public buildings energy consumption 50%, 40% of industrial enterprises with zero carbon emissions.**

Low-carbon Olympic area

- **Renewable energy use ratio:**
  - **By 2030, of electricity consumption 80%, cities and towns transportation 100%, urban and countryside residents' livelihood power consumption 100%, commercial & public buildings energy consumption 100%, 100% of industrial enterprises with zero carbon emission.**

Background

In the renewable energy development plan, it is cited that:

- **Rich wind and solar energy should be consumed locally in priority, to optimize the regional energy structure and promote the ecological civilization degree.**
- **Wind power, solar energy, geothermal heating demonstration projects.**
- **By 2020, renewable energy heating area more than16 million square meters. By 2030, more than 90 million square meters.**

Source text:

- **“本规划的实施可充分利用当地丰富的风光资源，体现了低碳经济理念；通过就地消纳，有利于区域能源结构进一步优化和提升，生态文明程度得到提高，区域社会经济发展更加持续” 。**

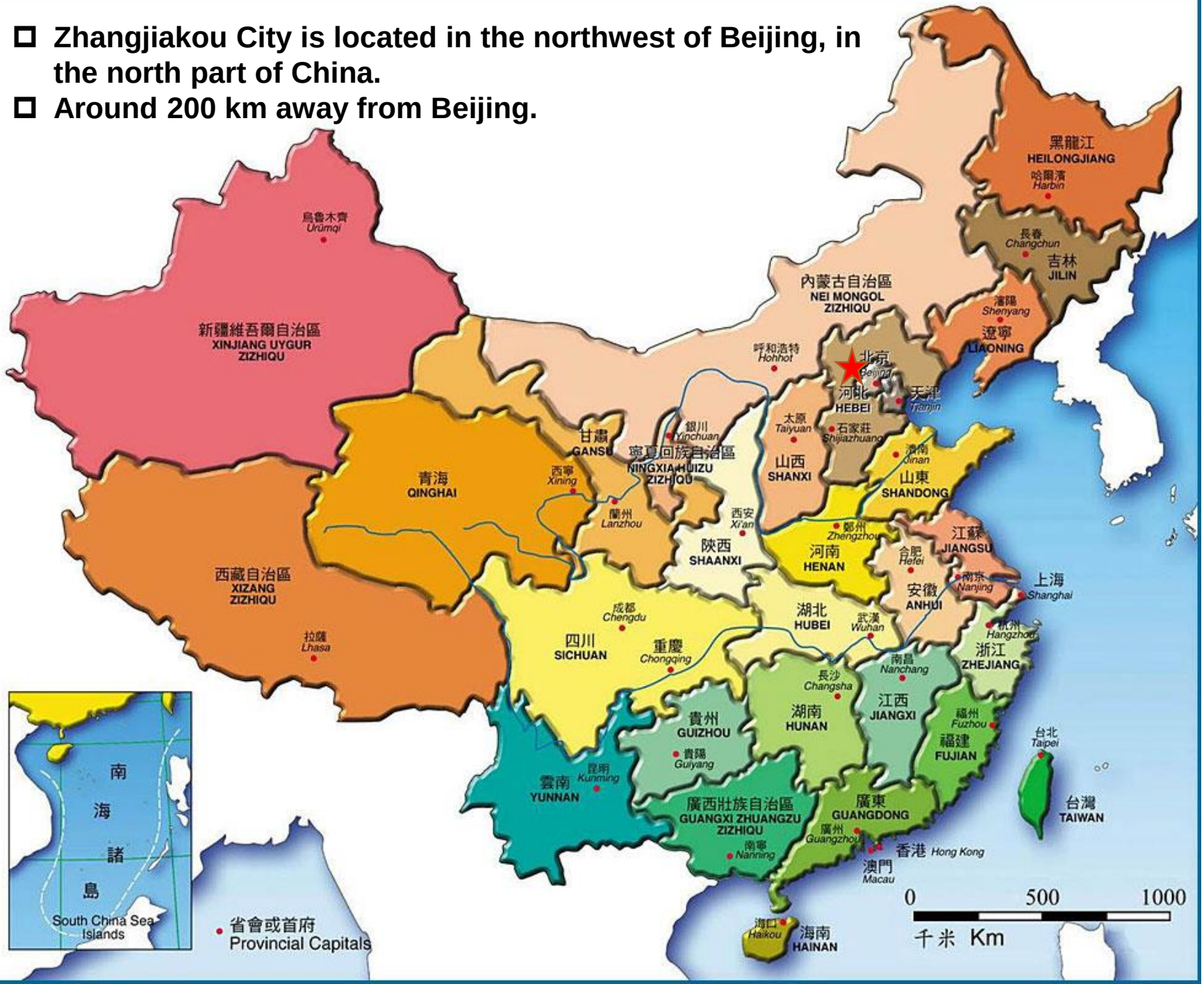
——数据来源：河北省张家口市可再生能源示范区发展规划，国家发改委2015年7月

- **积极推进风电、太阳能、地热供暖示范项目建设。到2020 年，市县主城区可再生能源供暖面积达 1600 万平方米以上，到 2030 年达9000 万平方米以上。**

——数据来源：河北省张家口市可再生能源示范区发展规划，国家发改委2015年7月

The characteristics of energy use in Zhangjiakou City

- Zhangjiakou City is located in the northwest of Beijing, in the north part of China.
- Around 200 km away from Beijing.



Energy consumption and Power generation

- The area of Zhangjiakou administrative region: 36800 km^2;
- The total population: 4.53 million;
- GDP: 135.9 billion RMB;
- Financial Revenue: 23.1 billion RMB;

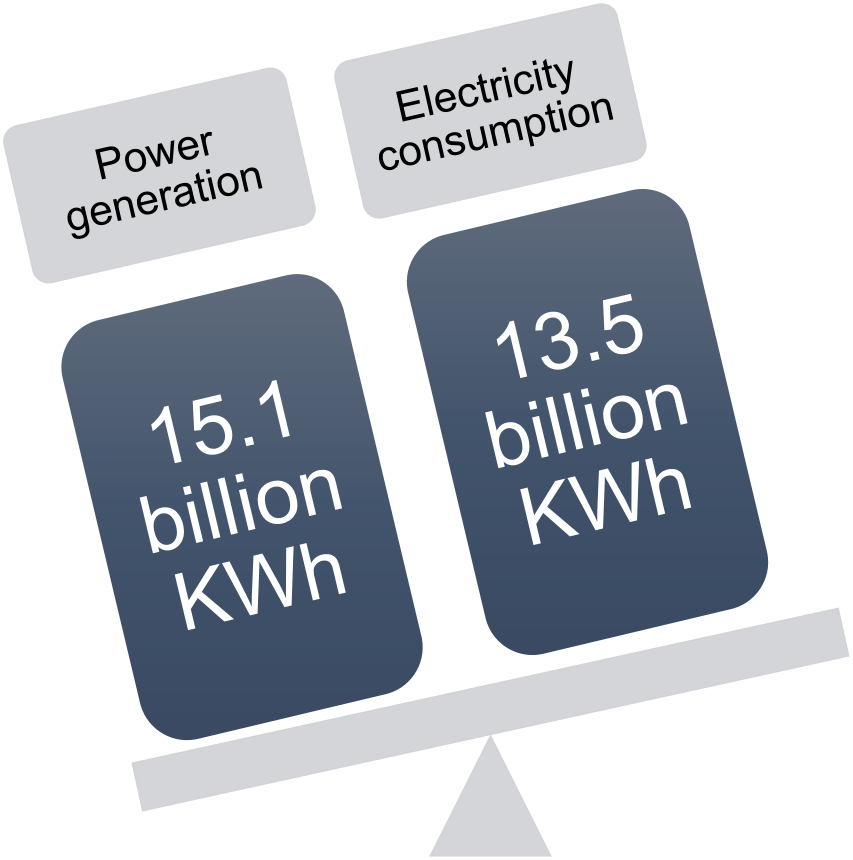
- Total energy consumption in 2013 is 17.63 million tons of equivalent coal, in which, 11.07 million tons of equivalent coal is used for industry;
- **Total electricity consumption in 2013 equals 13.5 billion KWh (4.45 million tons of equivalent coal).**

——Data source：Action plan of energy restructuring for 2022 Winter Olympics，Nov. 2014.

- **The annual renewable power installed capacity is 15.1 billion KWh (4.98 million tons of equivalent coal), including wind power 6.6 million KWh, solar PV 0.4 million KWh, straw biomass 25 thousand million KWh.**

——Data source: Development plan of renewable demonstration region in Zhangjiakou City, National Development and Reform Commission (NDRC), July, 2015.

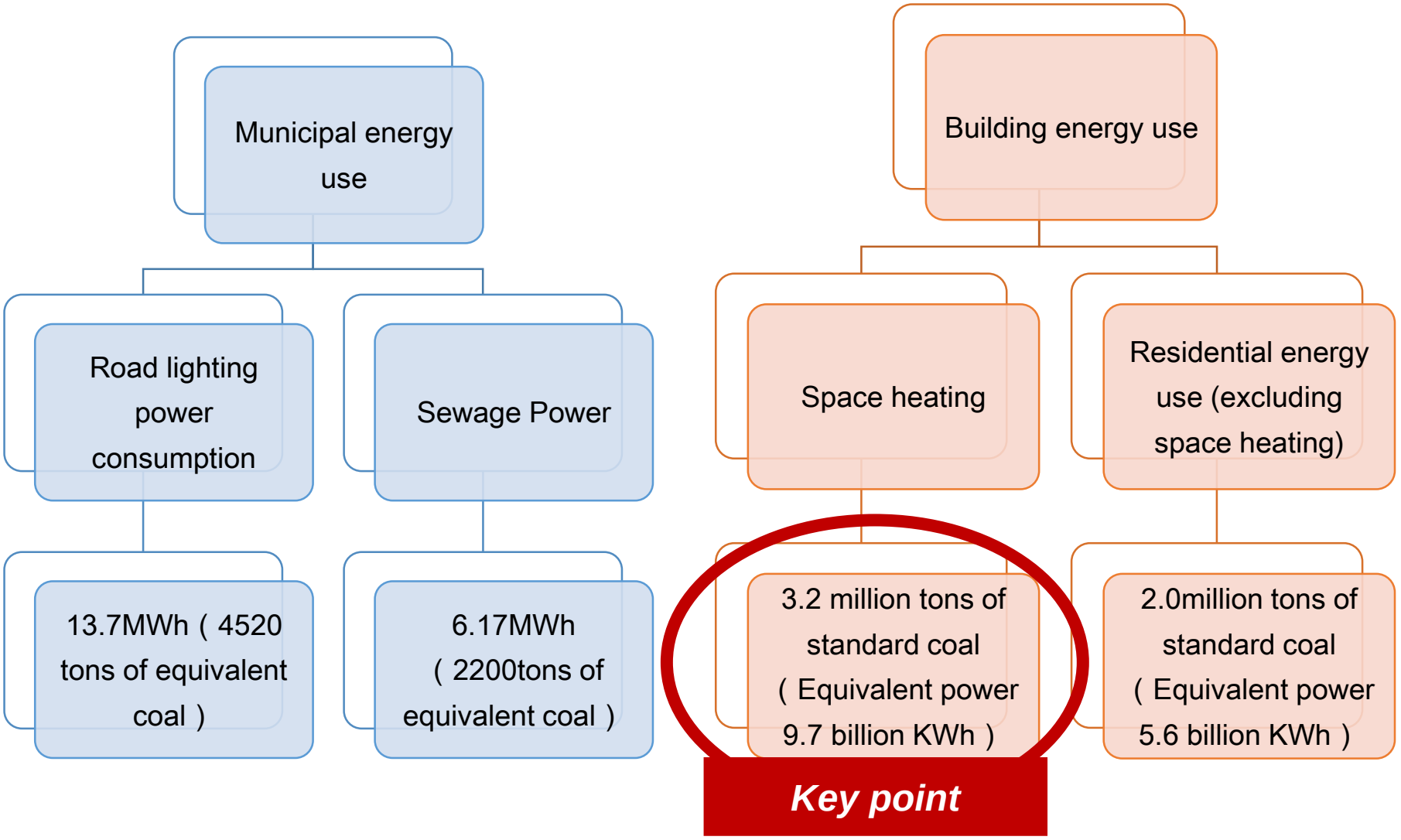
Energy consumption and Power generation



电力平衡已经负碳——就地消纳是重点！

Power balance has been carbon negative, Renewable energy local consumption is the key point！

Energy Load



——*Data source: Action plan of energy restructuring for 2022 Winter Olympics，Nov. 2014*

就地消纳的重点是建筑采暖

The key point of renewable energy local consumption is Building Space Heating.

The sustainable roadmap for building space heating in Zhangjiakou

The sustainable roadmap

Goal: Zero-Coal Low Energy

Innovative and key point

Make the best use of renewable energy network

Coupled consideration with building design

Follow the national standard building energy-efficient design and operation

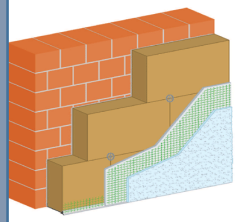
Step 3: Active space heating system — 0 W/m^2

Step 2: Passive solar house — 15 W/m^2

Step 1: Better thermal insulation — 20 W/m^2

Baseline: Current status — 43 W/m^2

Average space heating load of coal boiler



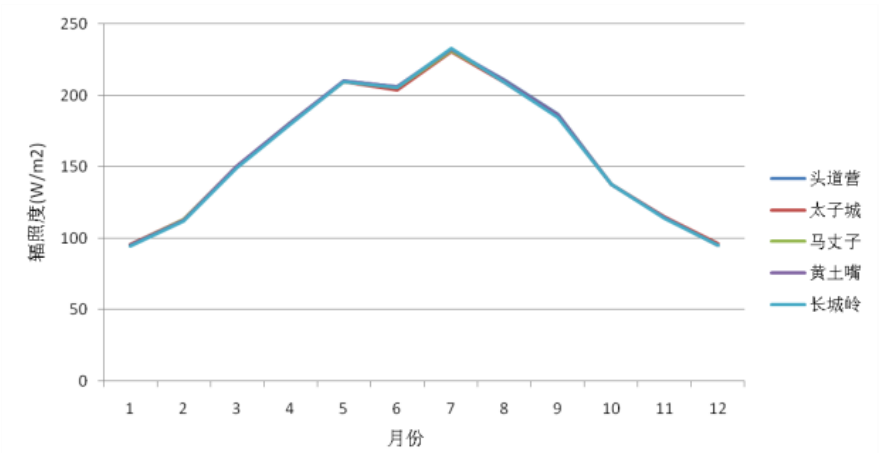
The sustainable roadmap - Step 1 (Better thermal insulation)

- **Thermal construction in walls, roofs, windows and doors, which should be higher than national and Hebei Province energy efficiency design standards, both for residential buildings and commercial buildings.**
- **Heating load of the buildings could be reduced at least 50%, from 43 W/m^2 to 20 W/m^2.**

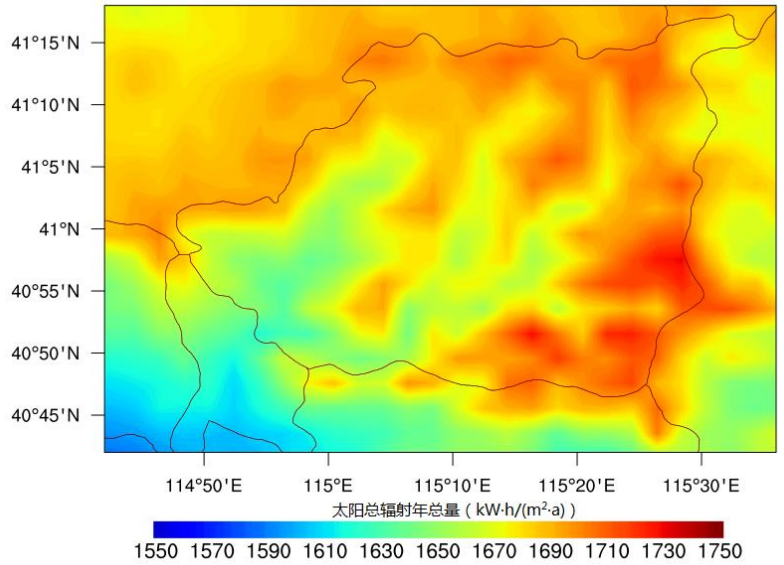
The sustainable roadmap - Step 2 (Passive solar house)

Solar irradiation

- **Annual sunshine hours 2800-3100h in most places;**
- **Total yearly horizontal solar irradiation 1600-1700 KWh/m^2;**
- **Better in summer, and lower in winter.**



Annual horizontal solar irradiation in several typical places in Zhangjiakou



Distribution of horizontal solar irradiation in Zhangjiakou

The sustainable roadmap - Step 2 (Passive solar house)

Solar-direct gain window

- Heat transfer coefficient of windows in the south facade should be less than 2.5 W/(m^2·K);
- Good **night thermal insulation** of the window;
- Suitable window-to-wall ratio in the south facade, 0.5 for rural houses;
- **Big thermal mass** in the room to reduce the temperature fluctuation.

Trombe wall

- Solar thermal wall in south

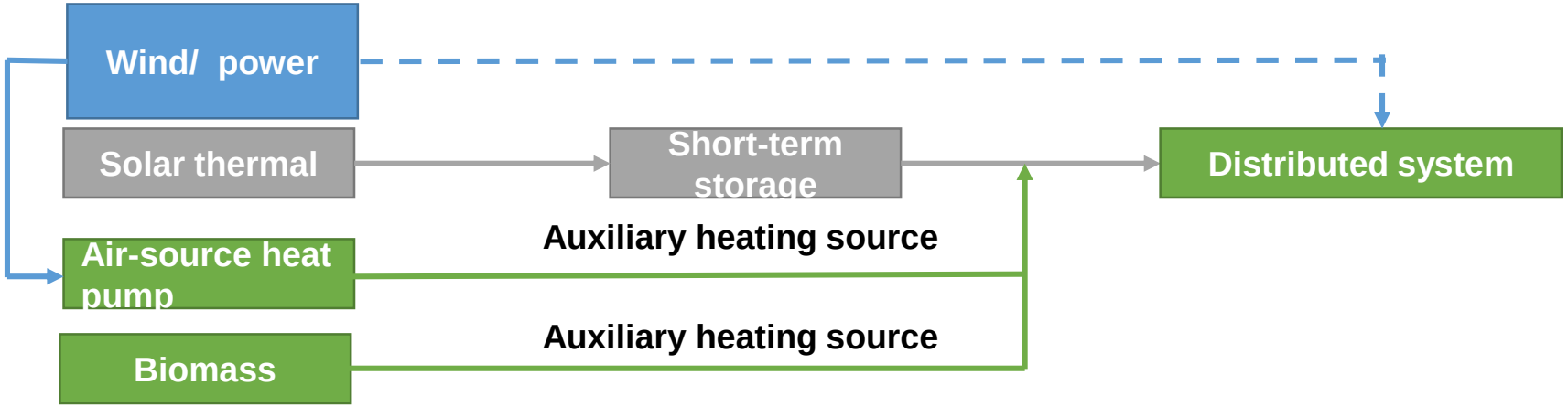
Sunspace

- The depth of the sunspace should be around 1.0-1.5 m;
- Heat transfer coefficient of windows in the sunspace should be less than 2.5 W/(m^2·K);
- Natural ventilation and shading should be considered in the sunspace design.

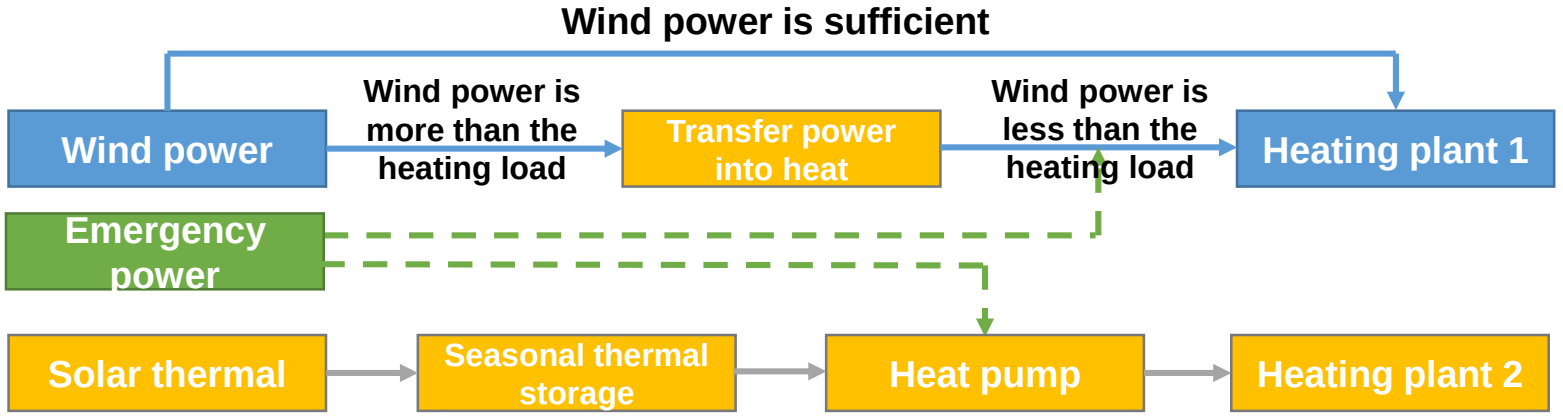
20 W/m² to 15 W/m²

The sustainable roadmap - Step 3 (Active space heating system)

Distributed system (for rural housing)



Concentrated system (for urban buildings)



The sustainable roadmap - Step 3 (Active space heating system)

Distributed heating system:

- There has already been many demonstration projects of renewable energy space heating system for rural housing, including solar water heating system, ASHP system, Ground-source heat pump system, and etc.

The sustainable roadmap - Step 3 (Active space heating system)

District heating plant:

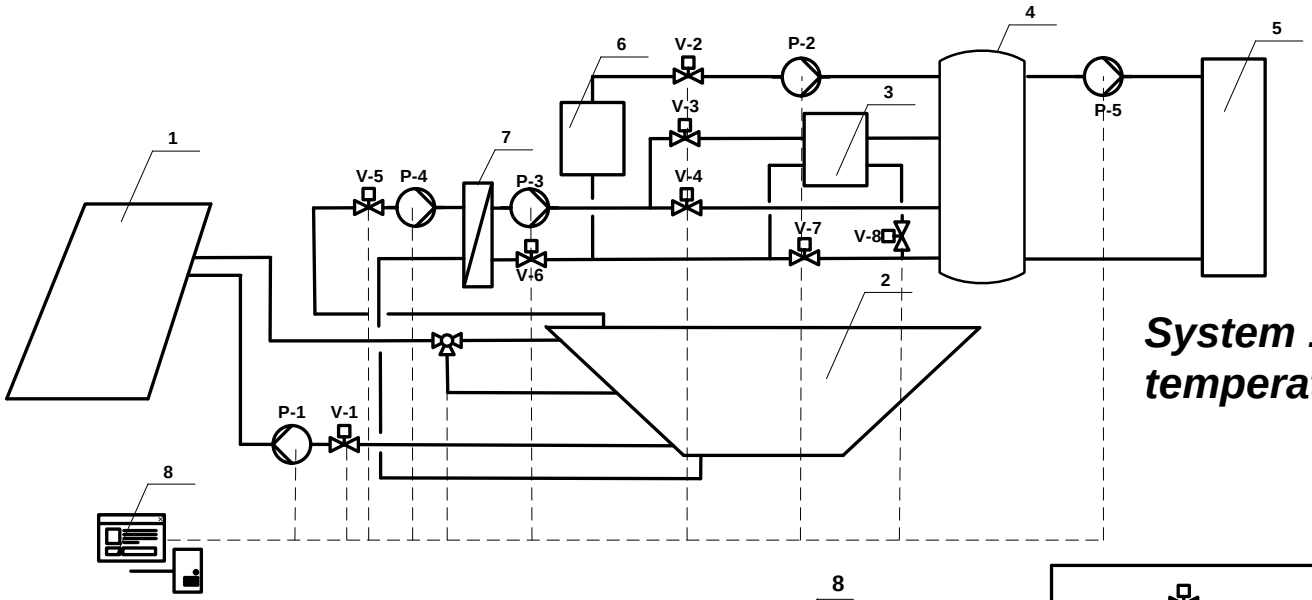
No.	Heating system	Initial cost (*10^4 RMB)	Life span （year）	Running fee(*10^4 RMB/year)	Heating price （RMB/m²）	Heating price （RMB/KWh）
1	District solar heating plant （solar fraction 0.92）	230000	20（solar collectors） 50（seasonal thermal storage）	22000	51.1	0.27
2	Electric boiler	16000	8	46654	93.2	0.49
3	Natural gas heating boiler	9377	8	43030	86.1	0.46
4	Natural gas combined heat and power generation	250000	20	343831	100 Electricity price 1.1RMB/kWh	0.53
5	Coal boiler	10000	20	6000	13	0.07

Calculation condition:

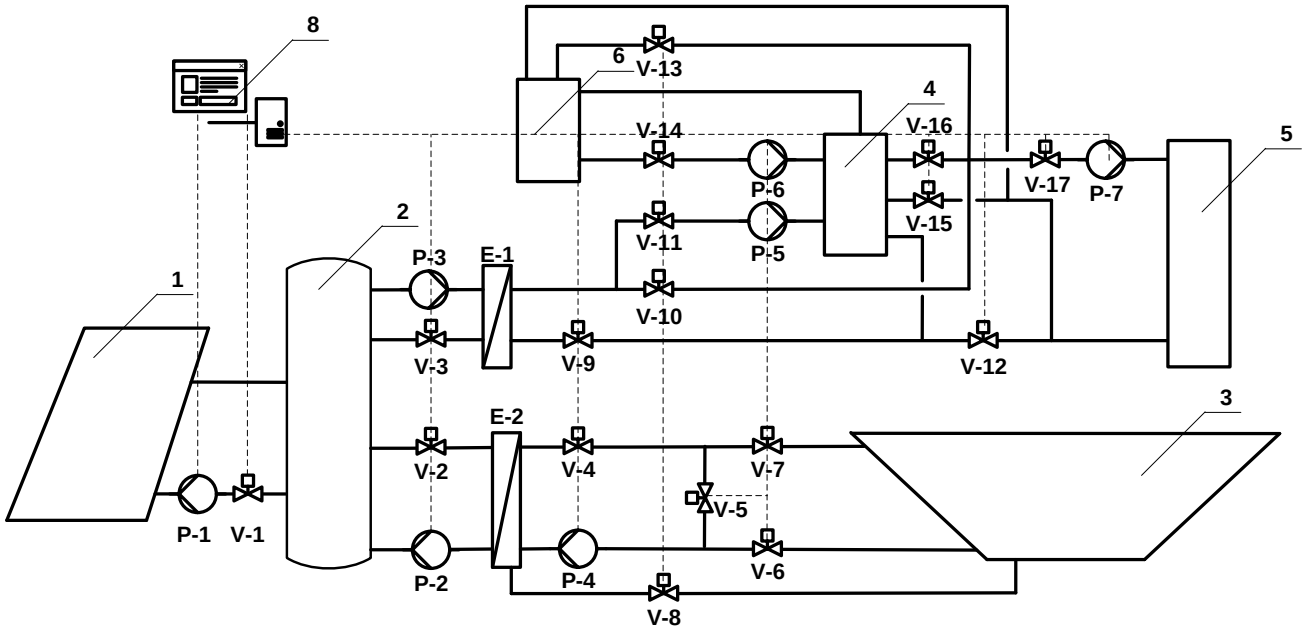
- Heating floor area: 1 million sq;
- Building annual average heating load index 43W/sq(the current situation), the peak heat load 75W/sq, heating period 183 days, family house 24 hours heating;
- Electricity price of natural gas 0.3 RMB /kWh, natural gas 3.6 RMB /m^3 , Coal-fired heating 37 RMB /kWh (2015-2016 Zhangjiakou) .

The sustainable roadmap - Step 3 (Active space heating system)

Schematic diagram of solar heating system with seasonal thermal storage



System 1. Water supply temperature less than 60 ℃



System 2. Water supply temperatures 80-95 ℃

What kind of collector for such case in Chongli?

Eff. Equation of various collectors

Based aperture area and mean temperature

$$\bar{\eta} = \bar{\eta}_0 - \bar{\alpha}_1 \frac{t_m - t_a}{G} - \bar{\alpha}_2 G \left(\frac{t_m - t_a}{G}\right)^2$$

1. U型管真空管集热器 U tube evacuated tube

= 0.69

=2.36 W/(m2 K)

=0.013 W/(m2 K2)

2. 热管真空管集热器 heat pipe evacuated tube

= 0.754

=1.405 W/(m2 K)

=0.005W/(m2 K2)

3．单层盖板平板集热器 one cover flat plate

= 0.756

= 4.895 W/(m2 K)

=0.010W/(m2 K2)

4．CPC真空管集热器 CPC evacuated tube

= 0.632

=0.317 W/(m2 K)

=0.010W/(m2 K2)

5．双层盖板平板集热器 double layers glaze covers

= 0. 721

= 1.32 W/(m^2 K)

= 0.011W/(m^2 K^2)

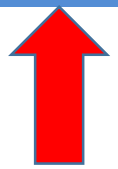
6、全玻璃真空管集热器（一次）all glass evacuated tube

= 0. 729

= 2.793 W/(m2 K)

Collector Eff. in mean temperature in Chongli, January

	40	50	60	70	80	90	100	110	120	130
U型管真空管集热器	0.429	0.370	0.307	0.240	0.168	0.092	0.011	-0.074	-0.163	-0.257
热管真空管集热器	0.534	0.503	0.470	0.436	0.400	0.363	0.323	0.282	0.240	0.196
单层盖板平板集热器	0.327	0.231	0.131	0.028	-0.079	-0.189	-0.302	-0.419	-0.539	-0.662
CPC真空管集热器	0.331	0.311	0.288	0.261	0.230	0.197	0.160	0.119	0.076	0.029
双层盖板平板集热器	0.532	0.493	0.451	0.405	0.356	0.302	0.246	0.185	0.121	0.053
全玻璃真空管集热器	0.474	0.428	0.382	0.337	0.291	0.245	0.200	0.154	0.108	0.063
槽式集热器	0.543	0.517	0.493	0.472	0.453	0.436	0.422	0.410	0.400	0.393
新型集热器	0.677	0.677	0.676	0.675	0.674	0.673	0.672	0.671	0.670	0.669



Chongli Ambient Temp.

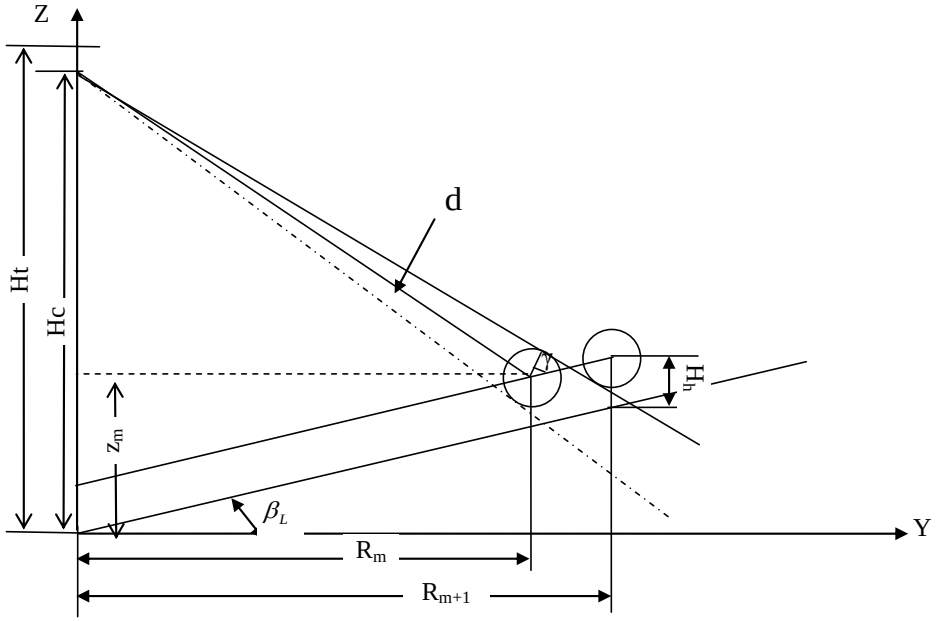
Month	daily lowest temp. /monthly
1	-14.3
2	-11.6
3	-3.5
4	1.9
5	12.8
6	16.6
7	18.5
8	17.3
9	10.8
10	3.7
11	-3.8
12	-10

To=94°C, Tm=90 °C
To=Demanded outlet temperature 94°C

Tm-Ta=Demanded outlet temperature：
92°C –(-14.3 °C)=110°C

Solar thermal tower in slope geo.

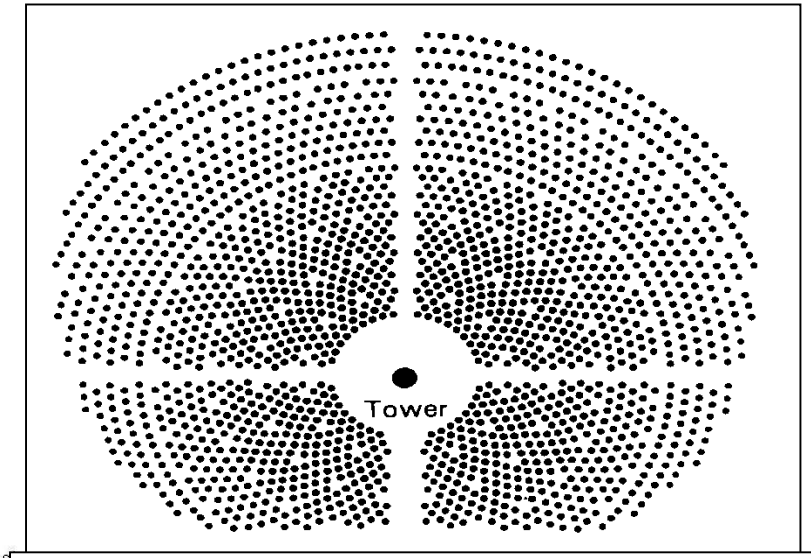
$$\Delta R_{\min} = R_{m+1,\min} - R_m$$

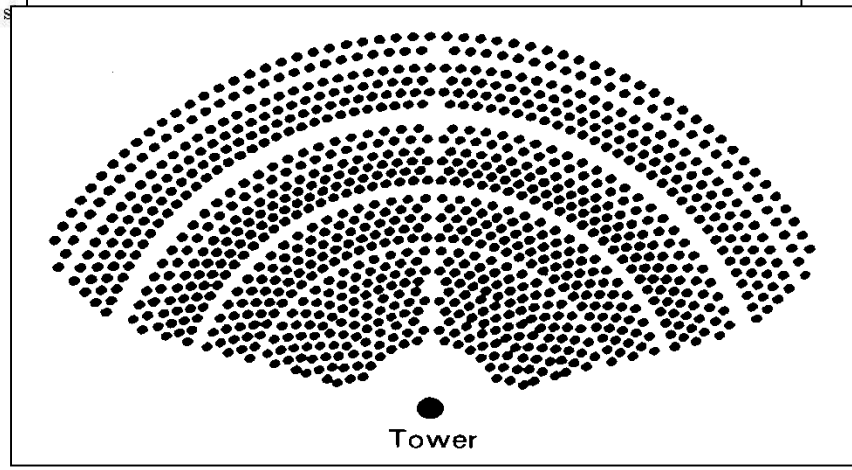


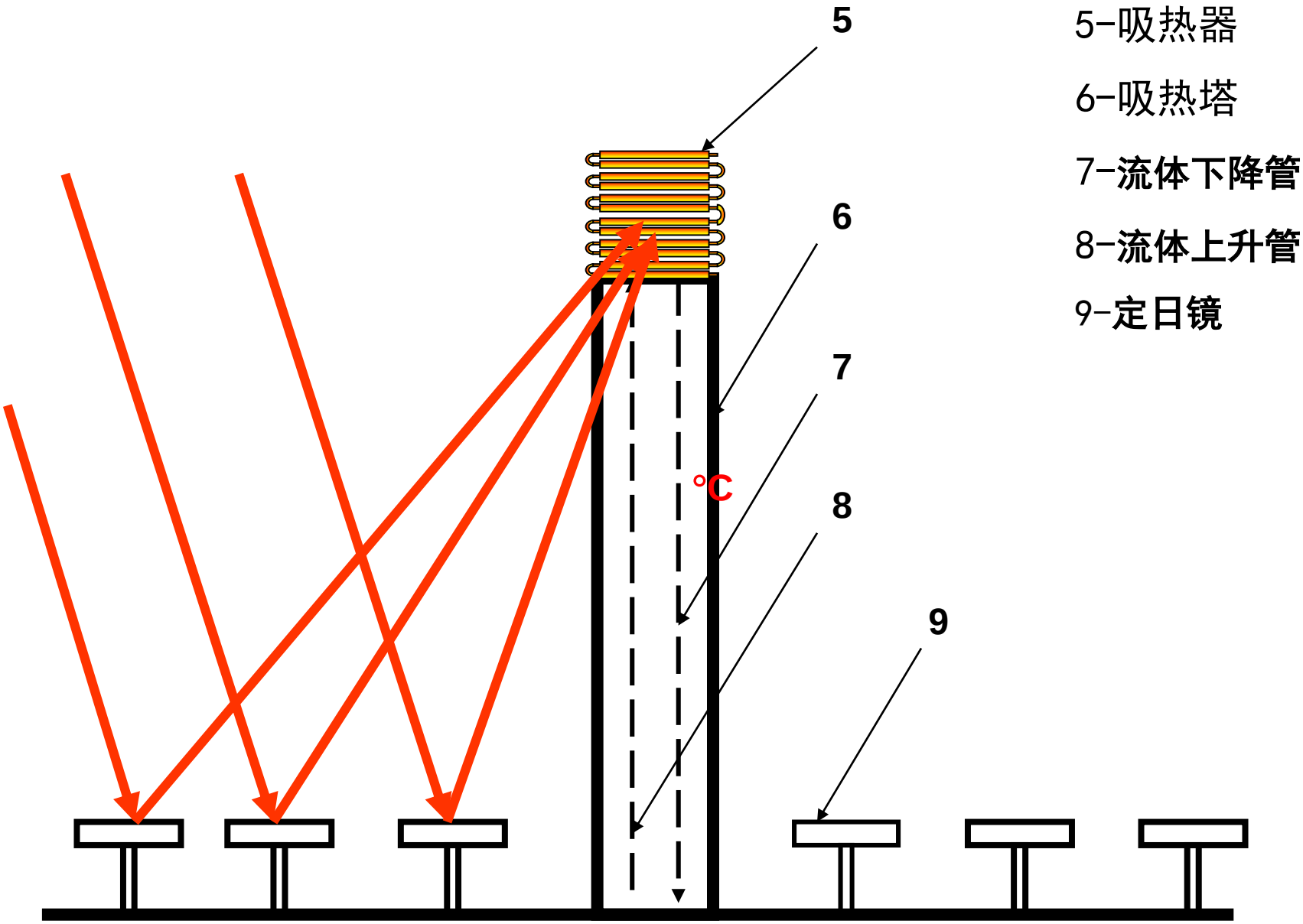
$$\Delta R_{\max} = R_{m+1,\max} - R_m$$

$$R_{m+1} = R_m + \Delta R_{\min} + R_{\min-\max}(\Delta R_{\max} - \Delta R_{\min})$$

$$0 < R_{\min-\max} < 1$$







5–吸热器

6–吸热塔

7–流体下降管

8–流体上升管

9–定日镜

图1　集热系统，北向视图

聚光吸热技术

Pat.真空管墙体式吸热器及系统

适合山体建设

40倍聚光比

= 0. 72

= 0.5-0.03 W/(m2 K)

专利号:201210316532.7

王志峰、张鸿斐、雷东强、白凤武、李鑫

The sustainable roadmap

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Coupled consideration with building design

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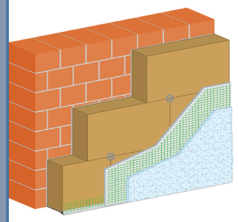
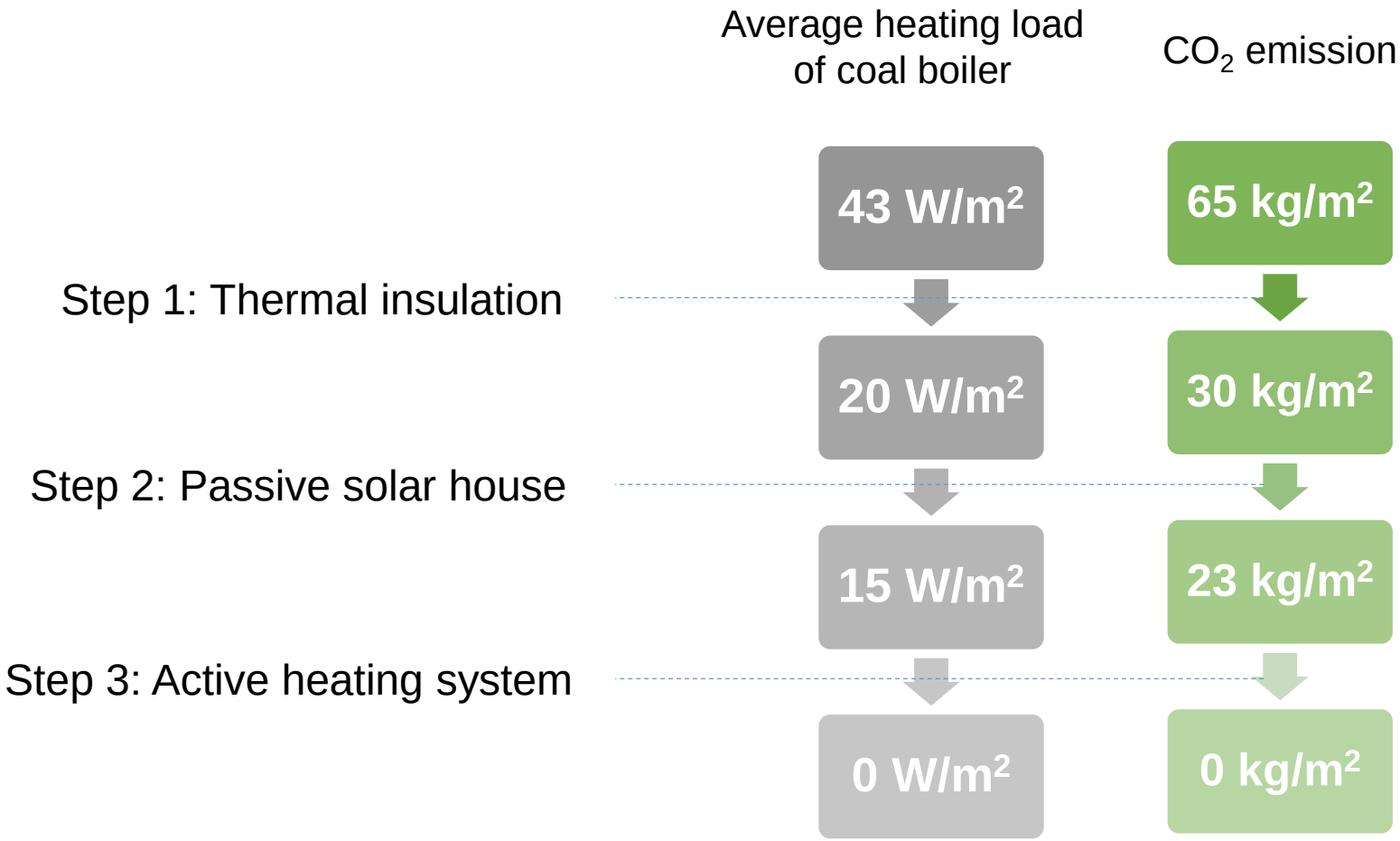
Average space heating load of coal boiler



The sustainable roadmap



谢谢聆听
Thank you

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The sustainable roadmap - Step 3 (Active space heating system)

For a typical rural housing with heating floor area 80 m^2. The economic characteristics is shown that:

Space heating system	Initial cost (*10^4 RMB)	Annual running fee with financial price subsidy (RMB/m^2 year)	Annual heating price with financial price subsidy (RMB/m^2 year)	Annual running fee without financial price subsidy (RMB/m^2 year)	Annual heating price without financial price subsidy (RMB/m^2 year)
Air-source heat pump (air supply)	0.9-1.1	6.3-10.0	11.9-16.9	10.2-16.6	15.8-23.4
Air-source heat pump (water supply)	1.6-2.0	10.0-13.8	20.0-26.3	26.4-38.9	36.4-51.4
Solar thermal +Air-source heat pump (water supply)	4.0-6.5 (Solar fraction 0.2)	4.4-8.8	29.4-49.9	10.7-22.3	35.7-62.9
Solar thermal + Ground-source heat pump (water supply)	5.0-7.0	4.4-8.8	35.6-52.5	10.7-22.3	41.9-66.0
Electric boiler (water supply)	0.9-1.2	31.3-37.5	42.5-52.5	66.9-122.7	78.1-137.7

- Financial price subsidy: From 4:00-21:00, 0.4483 RMB/KWh. **Other time period, 0.100RMB/KWh**
- Without financial price subsidy:
  - Accumulated electricity consumption <=2440 KWh, 0.4883RMB/KWh
  - Accumulated consumption varies between 2440 to 48800 KWh, 0.5883RMB/KWh
  - Accumulated electricity consumption>4880 KWh, 0.7883RMB/KWh
- Running fee: only system running cost + maintenance cost
- Heating price: system running cost + maintenance cost + depreciation