

Survey of Climate Conditions for Demonstration of a Large Scale of Solar Energy Heating in Xi'an

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Abstract: A special Energy-Efficiency Plan, for medium and long-term periods, was brought forward by the National Development and Reform Commission of China in 2005. Energy efficiency in buildings is highly emphasized in this energy planning. The Ministry of Finance, together with the Ministry of Construction P.R.C, is selecting cities with different climates to carry out demonstrations of renewable energy applications in buildings. Xi'an, a representative city in the West, is selected to demonstrate large-scale solar energy heating applications in urban residential buildings. In this paper, Xi'an's geographical situation and climate conditions are fully analyzed. The survey on solar energy resources, and the feasibility of solar energy heating on a large scale is also investigated. If this project is completed, the successful experience with respect to the solar energy application in Xi'an will be disseminated in the northwest regions of China. It is expected, after completion of this project, that design methods, procedures and installment of solar energy applications in residential buildings in Xi'an will be obtained.

Key words: Solar Energy; Solar Building; Heating

on surface tilted at latitude, $MJ/(m^2 \cdot day)$

H_o monthly averaged, daily total solar irradiation above the aerosphere, $MJ/(m^2 \cdot day)$

S_m monthly sunshine time, *hour*

K_t atmospheric clearness index

1. INTRODUCTION

Special Energy-Efficiency Plan during Medium and Long Term (2005-2020), is brought forward by the National Development and Reform Commission of China in 2005. Energy efficiency in buildings is one of ten key energy saving projects in this energy planning. The Ministry of Finance, together with The Ministry of Construction P.R.C is selecting representation cities to carry out demonstrations of renewable energy application in residential buildings. Xi'an, which is located in the western part of China, is selected to demonstrate the large scale solar energy application in urban residential buildings. Solar building integrated technology will be used in some residential buildings and public buildings. In this case, it would involve the residential buildings and public buildings heating-supply all year around. Technique of BIPV will be used in some residential buildings.

In this paper, Xi'an's geographical situation, as well as the climate is fully surveyed. Conditions of solar energy resources, the feasibility of solar energy heating on a large scale are also investigated. If the project is completed, the successful experience with respect to the solar energy application in Xi'an will be distributed use in northwest regions of China.

Nomenclature

T_a	average outdoor temperature, °C
H_t	monthly averaged, daily total solar irradiation on horizontal surface, $MJ/(m^2 \cdot day)$
H_d	monthly averaged, daily diffuse solar irradiation on horizontal surface, $MJ/(m^2 \cdot day)$
H_b	monthly averaged, daily direct solar irradiation on horizontal surface, $MJ/(m^2 \cdot day)$
H	monthly averaged, daily total solar irradiation

2. DISTRIBUTION OF SOLAR ENERGY RESOURCES

The solar is the base of all the renewable energies. Biomass energy, wind energy, solar energy, ocean energy, hydro energy and so on are all from solar energy. Broadly as speaking, all kinds of renewable energies belong to the solar energy. In general, the solar energy is referred to the radio energy of the sun. Solar heating technology is converted the radiant energy into heat by the solar collector.

The amount of solar energy resources is the key to judge whether the solar application is feasible or not. The total amount of solar radiant energy in various areas in China are different far from each other, and about from 3348 MJ/(m²·a) to 8371MJ/(m²·a); the average is 5860MJ/(m²·a), which is about equal to 1.2×10⁶ million tons of standard coal. The isograms of 5860MJ/(m²·a) is clear. It divided China into two parts from northeast to southwest (From the west of Da-Xing-An-Ling to the junction of Yunnan to Tibet)^[1]. On the basis of amount of the solar energy, China is divided in four areas, such as Tab. 1, its distribution as Fig. 1 below. It is the solar irradiation characteristic in China that the amount is higher in west than east and higher in north than the south^[2]. The solar irradiation is usually higher than 5860MJ/(m²·a) in northwest in China.

Tab. 1 Solar resources divisions in China^[3]

Resources divisions	Items	Solar irradiation [MJ/(m ² ·a)]
□	Richest resource areas	≥6700
□	Rich Resource areas	5400~6700
□	Common resources areas	4200~5400
□	Poor resource areas	<4200

3. HISTORY OF SOLAR APPLICATION IN CHINA

The history of using solar energy is rather long in China. People could get fire from the sun in the Western Zhou Dynasty before 3000 years ago. Generally speaking, the solar application mainly includes solar energy stove, solar water heating system, solar greenhouse, sun room, etc. By the end of 2005, the area of solar collector is beyond 700million m² in China, which accounts about the 60% in the world and the growth of the area of solar collectors reach to 27% in the past 10 years. Most the solar water heating systems are independent system, which usually cause the building roof promiscuity ,hot water pipes installed staggered disorderly, even the roof damaged, leaking and draining. For the purpose of energy efficiency, environmental protection and harmony with

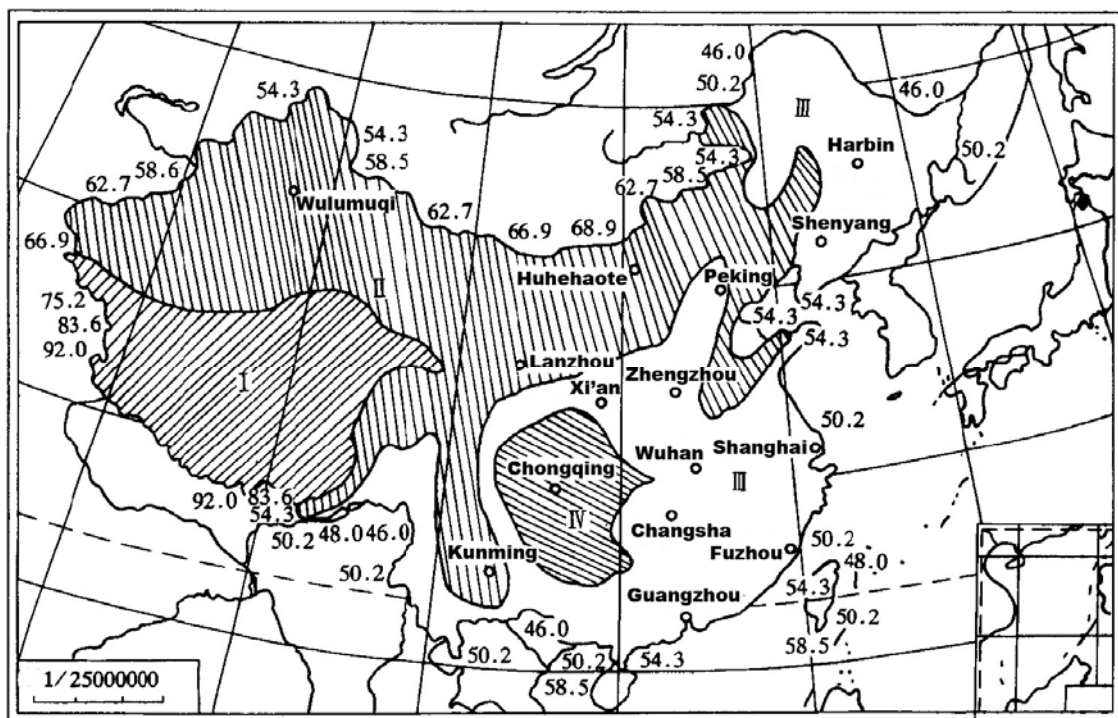


Fig. 1 Solar energy distribution of China (Unit: 100MJ/m²)

architecture, it would be the goal of the technology development; the solar water heating system and building integration will be the future direction of technology development and applications.^[4]

The economic development in the northwest is relatively backward areas in China. But at the same time, the solar energy resources are very rich, the total radiant energy in 5900~8400MJ/ (m² • a). The first solar building was built in Wuwei, Gansu province in 1975^[5], and after then, the passive solar building and initiative solar building in the northwest are widely applied step by step. In September 1979, the first national conference of experience exchanging for solar energy utilization held in Xi'an, to discuss the development of a national solar energy development of long-term planning, convened the inaugural meeting of the Chinese Solar Energy Society, founded the "Acta Energiae Solaris Sinica" and the "Solar Energy" journal^[6]. It accelerated application of solar energy in the northwest in China. Today, 25 years later, Xi'an is selected to demonstrate the large scale solar energy application in urban residential buildings, which will again promote the solar applications in Xi'an and northwest China; solar energy building integration technique will be generalized and applied.

4. CLIMATE AND SOLAR ENERGY RESOURCE ANALYSIS

Xi'an is located between east longitude 107°40'~109°49' and north latitude 33°39'~34°45', It is in the Central Guanzhong basin and it belong to the Yellow River basin. It is at the center of the geographical map in China (The mother earth origin of china is at Jingyang county Yongle town Shiji Temple near to Xi'an). It is located in a gas-humid zone of the monsoon climate, with four seasons, a moderate climate. The January, April, July and October as the representatives seasons of winter, spring, summer and autumn, the average temperature is 13.3□, precipitation about 600mm, humidity about 69.6%, frost-free period 207 days, sunshine 1912.8 hours, the coldest month is January and the average temperature is -0.9□, the hottest months in July and the average temperature is 26.6□, rainfall mainly in

Jul, Aug , Sep, an average of snows is 13.8 days. In general, the first snow is in November and the last in mid-march. The Tab. 2 shows the detailed meteorological parameters of Xi'an, and the Fig. 2 shows the daily average temperature all-year. The mainly wind direction is north-east and south-west. The wind speed is littler than 4m/s and the calm period is 30%. The Fig. 3 is the wind rose of Xi'an and it shows wind frequency, wind direction and wind force scale.

Tab. 2 Climate parameters in Xi'an

Items		Parameters	
Atmospheric pressure (hPa)	Winter	978.7	
	Summer	959.2	
Outdoor Calculated dry-bulb temperature (°C)	Winter	Heating	-5
		Air-conditioning	-8
		Ventilation	-1
	Summer	Ventilation	31
		Air conditioning	35.2
		Daily average of Air-conditioning	30.7
		Average daily range	8.7
Summer air-conditioning accounting wet-bulb temperature (°C)		26	
Hottest monthly average temperature (°C)		26.6	
Coldest monthly average temperature (°C)		-0.9	
Outdoor accounting humidity relative(%)	Winter air-conditioning	67	
	Hottest monthly average	72	
	Summer ventilation	55	
Win speed (m/s)	Winter average	1.8	
	Summer average	2.2	
Frost-free period(day)		207	
Average sunshine(hour/year)		1912.8	
Coldest temperature(°C)		-20.6	
Hottest temperature(°C)		41.7	
Raining seasons		Jul Aug Sep	
Annual average snowfall(day)		13.8	

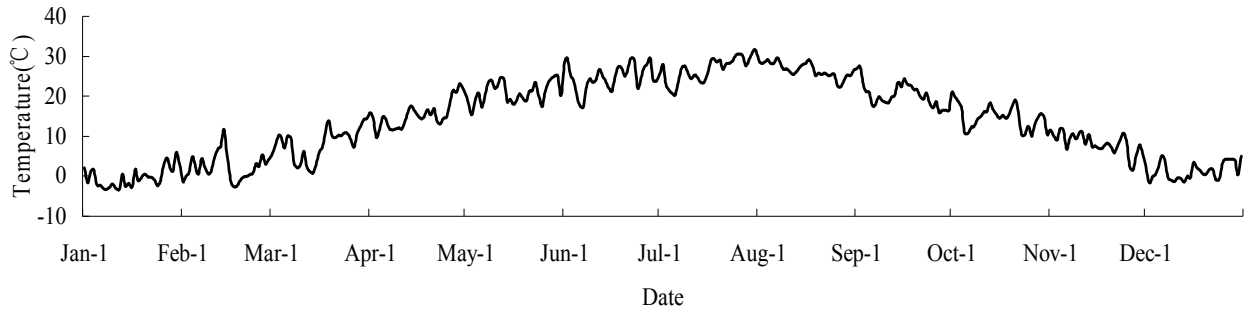


Fig. 2 Annual average temperature in Xi'an

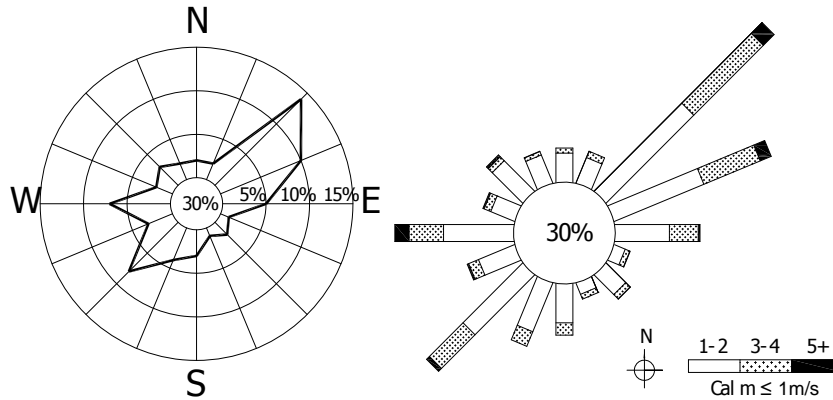


Fig. 3 Wind rose in Xi'an

According to solar radiation belt division in China, Xian is classified as □ areas, the applicable areas, the average sunshine 1912.8hours/year, the total annual solar radiation energy for 4771MJ/ (m² · a), the total heating season solar radiation energy to 1352MJ/m². According to solar radiation data [7], Xi'an's daily average sunshine is shown in Fig. 4, the total daily solar radiation shown in Fig. 5, a month solar radiation shown in Fig. 6. Xi'an's daily average sunshine curve shows that the average of sunshine is 4~7.2hours year around. The average sunshine time is high from June to August, and it is about 7 hours a day. In winter, however, the average sunshine time is 4 hours a day. Annual daily average sunshine has little fluctuations. In comparison, Fig. 5 shows the solar irradiation day-by-day all year in Xi'an. The

curve shows that solar irradiation day-by-day all year has the same trends as the curve of monthly daily average sunshine in Xi'an. The summer's daily solar irradiation is higher than other season. However, the fluctuation of the solar irradiation day-by-day all year is not outstanding.

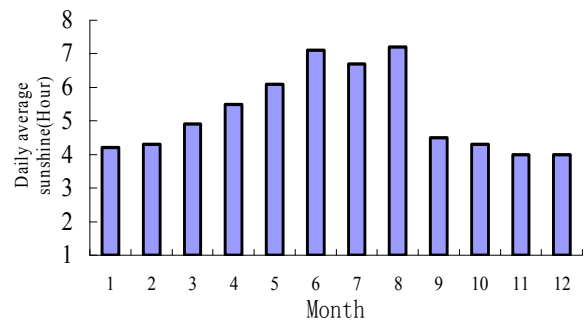


Fig. 4 Monthly daily -average sunshine in Xi'an

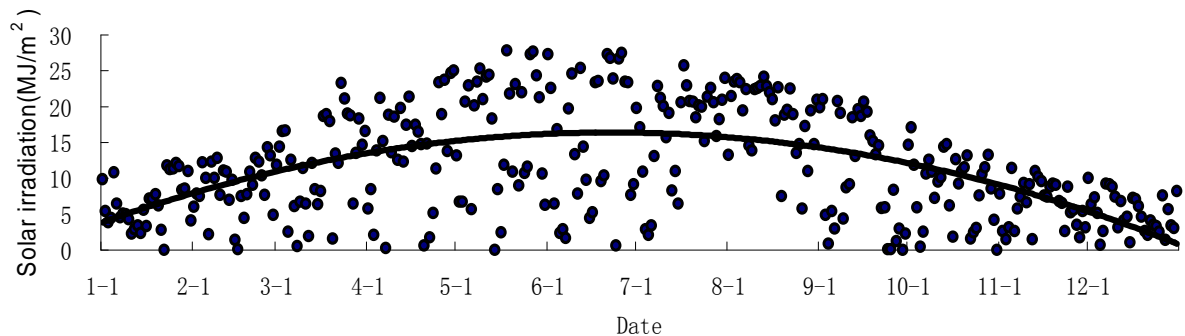
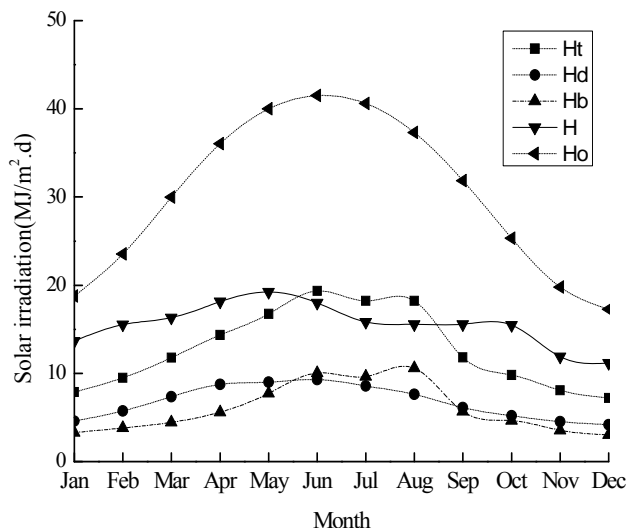


Fig. 5 Solar irradiation day-by-day all year in Xi'an

Tab. 3 Solar radiation parameters in Xi'an

Month	1	2	3	4	5	6	7	8	9	10	11	12
T_a	-1.0	2.1	8.1	14.1	19.1	25.2	26.6	25.5	19.4	13.7	6.6	0.7
H_t	7.884	9.513	11.796	14.359	16.756	19.363	18.232	18.213	11.816	9.822	8.075	7.214
H_d	4.585	5.734	7.352	8.743	9.011	9.315	8.573	7.628	6.137	5.201	4.527	4.199
H_b	3.299	3.823	4.454	5.616	7.744	10.048	9.659	10.593	5.686	4.643	3.548	3.021
H	13.667	15.550	16.310	18.142	19.225	17.992	15.837	15.559	15.579	15.471	11.901	11.186
H_o	18.788	23.546	29.987	36.054	40.010	41.504	40.600	37.321	31.874	25.333	19.795	17.260
S_m	105.3	107.5	125.5	153.8	178.1	192.0	198.7	202.3	132.0	115.7	102.8	97.4
K_t	0.420	0.404	0.393	0.398	0.419	0.466	0.449	0.488	0.371	0.388	0.408	0.418

Tab. 3 shows Xi'an's solar irradiation parameters. The curve of the monthly average solar irradiation is shown in Fig. 6. The solar irradiation ranges are from 11.186 MJ/(m²·day) to 19.225MJ/(m²·day) when the solar collector installed tilted at latitude.

**Fig. 6 Monthly Solar irradiation in Xi'an**

5. CONCLUSION

In this paper, the distribution of solar energy resource in China, especially the solar energy stations state in Xi'an, the experience of using solar energy in Chinese north-west is discussed, the climate of solar energy heating on a large scale and the solar distribution in Xi'an is analyzed. The conclusions are draw as follows.

(1) In Xi'an, the solar resources are applicable, and the solar irradiance distributes evenly in the whole year, which can perfectly meet the need of the solar buildings integrated on a large scale solar energy heating.

(2) The solar application in Xi'an and the

north-west has long history. Those successful experiences in the past are worthy to be studied further for the solar building integrated on a large scale solar energy heating in Xi'an.

(3) The solar demonstration on a large scale heating are favorable for solar energy applications in Xi'an and in west or other areas in China.

6. ACKNOWLEDGEMENT

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