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Climate Warming and Energy Consumed for Winter Heating in Xi'an

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Abstract: The accumulated negative temperature, the first heating date, the last heating date, heating duration, collective heating area and energy consumption for winter heating in Xi'an during 1986−2002 were comprehensively analyzed. The results show that under the global warming, winter in Xi'an became warmer and heating duration shorter. With the development of economy, the area and energy consumption for collective heating increased continually. In the meantime, the energy consumption per unit area for winter heating decreased year by year, but it did not match the winter temperature well because the energy was not proportionally consumed according to the change of temperature. In order to conserve energy effectively, heating in winter should be timely adjusted according to actual temperature change.

Key words: climate warming; energy consumption; heating; energy conservation

Introduction

According to the heating and ventilation standard of China, the heating period is the period when the daily average temperature is stably below or equal to the critical outdoor temperature of 5 ℃ [1]. With climate warming, it is reasonable to expect that the winter heating period and energy consumption will decrease in theory. However, in fact, the key problem is whether winter heating is reasonably adjusted or not according to daily temperature change. Therefore, over the past decade, a few researches have focused on the impact of climate warming on winter heating in different countries [2−5], and the impact of climate warming on the energy consumption of heating in winter and economy structure [6−8]. In China, improving energy efficiency is an important way to change the economy growth mode. Energy saving not only has the direct impact on guaranteeing energy supply, promoting technology progress and improving economy benefit, but also is an important way to protect the environment and to reduce carbon dioxide emissions. Therefore, in this paper, based on the fact of climate warming in winter and the winter heating in Xi'an, the effects of temperature changes in winter on the energy consumption of heating are analyzed in order to provide references for the design of the energy consumption of heating.

1 Historical evolution of temperature during heating period

The data used in this section are the daily climatic data of Xi'an from 1951 to 2003. The heating period was calculated based on temperature data according to the heating and ventilation standard of China [1], and it is generally from the middle or late November of first year to the early or middle March of next year, for example, the heating period in 1951 refers to that in the 1951/1952 winter.

The accumulated negative temperature of daily minimum temperature is the sum of the absolute value of daily minimum temperatures lower than 0 ℃ in winter half year. There were close correlations among accumulated negative temperature, yearly extreme minimum temperature, monthly mean temperatures and monthly mean minimum temperatures in winter in Xi'an [9], indicating that the interannual change of accumulated negative temperature is able to well represent the temporal

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evolution of winter coldness/warmth. The larger the accumulated negative temperature, the colder the winter, and the higher the energy consumption of heating; and vice versa. Figure 1 shows the temporal evolution of accumulated negative temperature and heating period from 1951 to 2002. It can be seen from Fig. 1 that yearly accumulated negative temperature changed remarkably. It reached the maximum value of 561 ℃ in the winter of 1954/1955 and the minimum value of 103 ℃ in the winter of 2001/2002, and in 2002/2003 it was 208 ℃, which was still significantly lower than the long term mean of 312 ℃ over 1951−2002. The trend line of accumulated negative temperature in Fig. 1 is a curve of natural logarithm, which is the best one selected from straight line, natural logarithm, quadratic exponent, power function and natural exponent fittings, and it shows that the accumulated negative temperature decreased year by year, indicating that winter in Xi'an has gradually become warmer. Figure 1 also shows that although the variation of heating period changed greatly from one year to another, it generally shows a decrease trend, indicating that the heating period has become shorter and shorter.

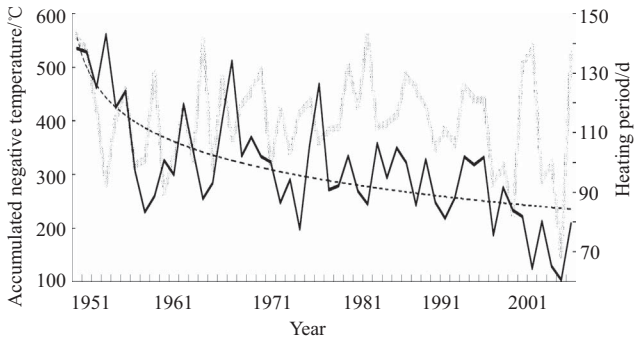

Fig. 1 Temporal evolution of accumulated negative temperature (solid line), its trend (dashed line) and heating period (heavy solid line)

2 Correlations between climate warming and energy consumption of heating in winter

2.1 *Data and analysis*

The heating energy consumption data used in this section were collected from Xi'an statistical yearbooks during 1986−2002. In common climatic data, the first heating date, the last heating date, the heating duration and the accumulated negative temperature were listed cross-year. However, the heating energy consumption data in statistical yearbooks were given from January 1 to December 31 in one year. Therefore, the climatic data used in this section were analyzed with non-cross-year method.

The way to count the number of the first/last heating day is that November/March 1 is marked as 1, November/March 2 as 2, and so on, and the date before November/March 1 is marked as negative integer. The number of heating days in a year is determined by the cumulated days from January 1 to the last heating date and from the first heating date to December 31 in the year.

2.2 *Analysis of heating energy consumption*

2.2.1 *Changes of total area and energy consumption for collective heating*

With the development of national economy and the improvement of living standards, the area for collective heating increased continually in Xi'an in the last 20 years. Changes of yearly total area and energy consumption for collective heating from 1986 to 2002 are shown in Fig. 2. The collective heating area was less than 2.40 million m^2 in the middle-late 1980s, however it reached 8.4 million m^2 in the 1990s and 11.76 million m^2 in 2002, respectively. The mean increasing rate for collective heating area was 0.10 million m^2 per year, which was mainly a result of the increase of urban population and the improvement of housing condition.

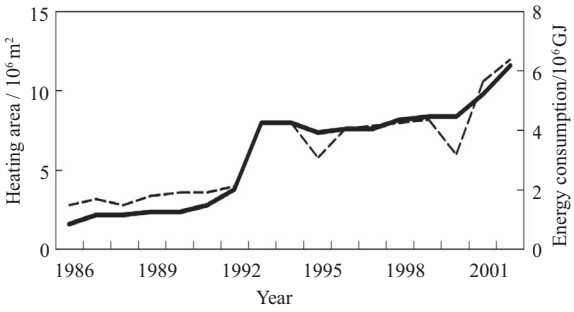

Fig. 2 Temporal evolution of the total area (solid line) and energy consumption (dashed line) for corrective heating

The total energy consumption was becoming higher accordingly with the increase in total collective heating area. It was only less than 1.90 million GJ in the 1980s, but it reached 4.40 million GJ in the 1990s and 6.48 million GJ in 2002, respectively, suggesting that the total energy consumption for collective heating increased at a high rate.

2.2.2 *Changes of heating energy consumption per unit area and heating period*

Temporal evolution of the first/last heating date from 1986 to 2002, determined according to the heating and ventilation standard of China [1], are shown in Fig. 3. There were no obvious changes of the general trend of the first heating date from 1986 to 2002, however, its interannual variation was larger, with the earliest date on November 7

(2000) and the latest date November 30 (1998). There was an obvious advancing trend for the last heating date from 1986 to 2002, indicating that the period of cold weather in winter was getting shorter. The interannual variation of the last heating date was also large, with the earliest date on February 5 (2002) and the latest date on March 27 (1987).

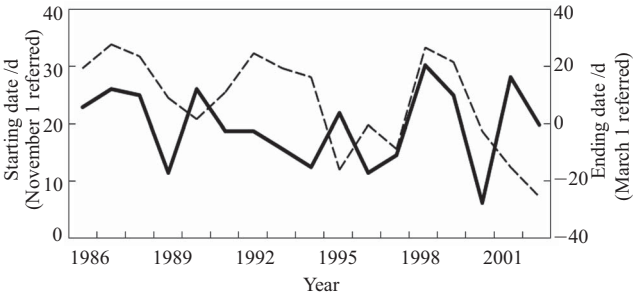

Fig. 3 Temporal variations of the starting (Solid line) and ending (dashed line) dates for winter heating during 1986−2002

Changes of heating period and heating energy consumption per unit area during 1986−2002 are displayed in Fig. 4. It is seen from the figure that there was an obvious reducing trend of heating energy consumption per unit area, and it was 0.85 GJ/m^2 in the middle-late of 1980s and 0.55 GJ/ m^2 in 2002, respectively. Figure 4 clearly shows that there was an obvious reducing trend for the day number of winter heating period from 1986 to 2002, thus also indicating that the cold period in winter was getting shorter.

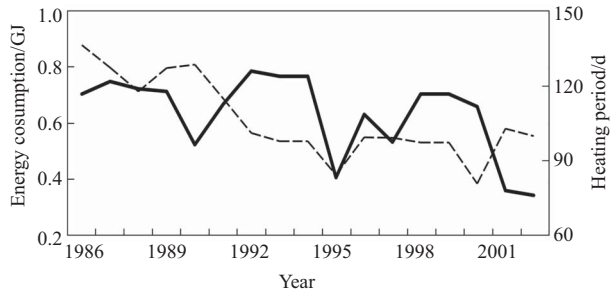

Fig. 4 Temporal variations of heating period (solid line) and energy consumption per unit area (dashed line) during 1986−2002

Although both the heating period and heating energy consumption per unit area showed obviously reducing trends, they were not significantly correlated. The reason was that although the general trends of reducing heating energy consumption per unit area and climate warming in winter were similar, the winter heating period practically implemented in Xi'an was traditionally fixed from November 15 of the previous year to March 15. However, the first/last heating date, and the day number of heating period in different years based on climate condition are different. Therefore, there are great differences between the heating periods implemented in practice and determined from climate data in theory. The heating energy consumption per unit area decreased year by year, but there was no proportionally adjustment of the heating. Thus, there were little interannual changes of heating energy consumption per unit area, and it did not match the climate change well in different years. Therefore, there was no significant correlation between the day number of heating period and the heating energy consumption per unit area, suggesting that the present heating regime is irrational and should be timely adjusted.

3 Suggestions for energy conservation

The results of this study indicate that the interannual and daily variations of temperature are large in Xi'an. Accordingly, if the heating is not adjusted according to actual temperature change, then it will leads to excessive heating in warm days and deficit heating in cold days. Therefore, heating in winter should be adjusted according to actual temperature changes, and weather forecast should intensify the guidance to winter heating [9].

The statistical results of the climate data from 1951 to 2003 in this study also show that the first heating date ranged from November 7 to December 2, and the difference between them was 25 d. Similarly, the last heating date ranged from February 4 to March 28, and the difference was 52 d. Therefore, the first and last heating dates should be timely adjusted according to actual temperature changes to conserve energy effectively.

The energy consumption of winter heating is mainly determined by the duration of heating period and daily heating intensity. Currently, the heating period in winter in Xi'an is fixed and lasts for 121 d from November 15 to March 15 of the next year. According to the heating and ventilation standard of China [1], the mean number of heating days calculated from the temperature data from 1993 to 2002 is 103 d, i.e. 18 d less than the fixed heating period implemented in practice, and the reduction of 18 d in heating would account for 14% of the annual energy consumption of winter heating. Under the background of global warming, winter in Xi'an has become warmer in the past 20 years, and the heating period should be timely adjusted according to climate change.

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