Prediction of Heating Energy Consumption and Analysis of Energy Saving Potential in Northern Urban Areas of China

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Abstract. A classified energy consumption statistics method is established to analyze and predict the future energy consumption of heating in northern China. Firstly, according to the energy intensity and proportion of central heating and decentralized heating, combined with the building area of cities and towns in northern provinces, the heating energy consumption in 2018~2035 is predicted. Then the energy saving potential of heating is analyzed by the scenario assumption. The results show that controlling energy consumption intensity has obvious energy saving effect on heating in northern towns of China. If the intensity and proportion of heating energy consumption are regulated, the peak of total heating energy consumption in the northern region will appear in 2030, reaching 265 million tce.

1. Introduction

China is the world’s largest emitter of more than 6 billion tons of CO₂ into the atmosphere each year. Energy saving and emission reduction is a hot issue in China. With the development of society, the total energy consumption of buildings and its proportion in the energy consumption of social terminals are continuously increasing. One third of the total building energy consumption is that of heating in northern China[1]. A model of building energy consumption based on energy intensity and verified by statistical data was established by Tsinghua Building Energy Saving Research Center. And they concluded that the energy consumption of heating in northern urban areas of China was 201 million tce in 2017[2]. Compared with developed countries, the energy consumption per unit area of urban building heating in China is 2~3 times in that of the same latitude countries. Energy consumption in buildings other than heating, compared by unit area, is only 1/5~1/2 in developed countries[3]. So heating energy consumption still has great energy saving potential. At present, the energy consumption data of building central heating in China still need to be deeply analyzed, and the energy consumption of decentralized heating still lacks statistics. The purpose of this paper is to construct a statistical method of classified heating energy consumption, to predict heating energy consumption in the northern region, and then to analyze the potential of energy saving through scenario assumptions.

2. Method

At present, the heating system in north China is dominated by central heating and supplemented by decentralized heating. The research method of this paper is shown in figure 1. The total energy consumption of heating in northern towns is acquired by Formula (1)(2). Find out the energy consumption intensity of all kinds of heating methods, analyze the proportion of them, and then multiply the urban building area to get the total energy consumption of heating in northern towns. This paper takes 2018 as the base year, and the calculation formula is as follows:
\[
E = \sum_k \sum_i E_{k,i}
\]

(1)

\[
E_{k,i} = e_{k,i} \times A_k \times P_i
\]

(2)

- \(i\) - different heating types;
- \(K\) - different cities;
- \(e\) - heating energy intensity, kgce/(m\(^2\)·a);
- \(E\) - total heating energy consumption, kgce;
- \(A\) - urban construction area of different cities;
- \(P\) - proportion of various heating modes.

**Figure 1.** Heating energy consumption research method.

### 2.1. Heating energy intensity

China has no official statistics on the energy consumption of central heating. A top-down approach based on a statistical yearbook is used to study energy consumption in central heating. The "total steam heating" and "total hot water heating" of each province in the statistical yearbook of China are added as the central heating quantity, divided by the central heating area of each province, and the energy intensity of central heating in the northern region in 2018 is obtained.

Decentralized heating is mainly divided into five ways: small boiler, heat pump, domestic gas furnace, domestic coal stove and direct electric heating. The energy intensity of each type of decentralized heating varies according to the heating equipment. According to some annual reports of the electric power industry and statistical data of urban heating enterprises, energy intensity of various decentralized heating modes is determined in this paper.

Energy intensity of various heating modes in provinces is shown in Table 1[4-7]. Due to insufficient data acquisition at present, the energy intensity of various decentralized heating modes is assumed as the same in each northern province.

| central heating   | Beijing | Tianjin | Hebei | Shanxi | Inner Mongolia |
|-------------------|---------|---------|-------|--------|----------------|
|                   | 11.04   | 12.03   | 14.04 | 13.28  | 18.40          |
| Liaoning          | 16.73   | 15.21   | 19.23 | 12.65  | 11.76          |
| Shaanxi           | 12.43   | 16.15   | 16.18 | 22.72  | 17.47          |

| decentralized heating | small boiler | heat pump | domestic gas furnace | domestic coal stove | electric heating |
|-----------------------|--------------|-----------|----------------------|--------------------|-----------------|
|                       | 15           | 9         | 8.6                  | 20                 | 21              |

### 2.2. Heating mode proportion

From the research of terminal energy use in Tsinghua University, it is concluded from the bottom-up method that the area connected to the central heating pipe network in the northern towns of China accounts for about 80%. Decentralized heating for the remaining 20%[8]. In this paper, the calculation...
of energy consumption of central heating adopts the top-down method, which is different from their statistical caliber. The energy statistics in the statistical yearbook are for the industrial enterprises whose annual main income is more than 20 million yuan or whose annual comprehensive energy consumption is more than 10,000 tce. This part of energy consumption is classified as decentralized heating in this paper, so the proportion of central heating in this study should be less than 80%.

Combined with the large-scale household survey and the general survey of public buildings in some cities, various heating modes in north China are shown in table 2.

Table 2. The proportion of various heating methods.

| heating method       | central heating | small boiler | heat pump | domestic gas furnace | domestic coal stove | electric heating |
|----------------------|-----------------|--------------|-----------|----------------------|---------------------|------------------|
| proportion           | 70%             | 10%          | 3%        | 7%                   | 8%                  | 2%               |

2.3. Urban heating area
The total amount of all kinds of building areas in China was predicted by the building area per capita method. According to the population situation of each province in the statistical yearbook, the corresponding functional relation is used to map to each type of building area, so as to realize the dismantling of the total building area in China to each type of building area in each province. The prediction of urban construction area in northern provinces is shown in figure 2.

Figure 2. Urban construction area forecast in north China.

3. Scenario Analysis

3.1. Set the scene
If China can strictly implement the corresponding policies of building energy conservation, the energy intensity of various heating modes will be reduced and the proportion will also change. In this section, through the control variable method, four different scenarios are set to analyze the influence of heating energy intensity and its proportion on heating energy consumption in northern China in the future.

3.1.1. Scenario A. Assuming that the future of our country all kinds of heating energy consumption intensity and the proportion of the current state unchanged, the heating energy consumption only changes over the building area. According to the data of the above, The total energy consumption of
heating in each northern province from 2018-2035 can be calculated by Formula (1)-(2) under the condition of unchanged energy conservation level. The scene was compared as a basic scene.

3.1.2. Scenario B. Assuming that by improving the efficiency of boiler and pipe network and enhancing the insulation of building envelope, the energy intensity of various heating modes has changed (table 3), but the proportion remains unchanged. (Data for years between 2018 and 2035 are obtained by interpolation.)

| Central heating | Beijing | Tianjin | Hebei | Shanxi | Inner Mongolia |
|-----------------|---------|---------|-------|--------|----------------|
|                 | 7.62    | 8.30    | 9.69  | 9.16   | 12.69         |
| Liaoning        | 11.55   | 10.50   | 13.27 | 8.73   | 8.11          |
| Shaanxi         | 8.57    | 11.14   | 15.68 | 11.17  | 12.05         |

| Decentralized heating | Small boiler | Heat pump | Domestic gas furnace | Domestic coal stove | Electric heating |
|-----------------------|--------------|-----------|----------------------|---------------------|-----------------|
|                       | 9.8          | 9         | 7.8                  | 15                  | 20              |

3.1.3. Scenario C. By expanding the scale of central heating and reducing the use of heating equipment with high energy consumption and high pollution, the proportion of various heating modes has changed. The proportion of various heating modes is set as shown in table 4.

| Heating method | Central heating | Small boiler | Heat pump | Domestic gas furnace | Domestic coal stove | Electric heating |
|----------------|-----------------|--------------|-----------|----------------------|---------------------|-----------------|
| Proportion     | 80%             | 6%           | 2%        | 8%                   | 2%                  | 2%              |

3.1.4. Scenario D. Suppose that the energy intensity and proportion of all types of heating in China in the future have changed, and the change amount is the same as scenario B and C.

| (million tce) | 2018 | 2020 | 2025 | 2030 | 2035 |
|---------------|------|------|------|------|------|
| A             | Central heating | 141 | 160 | 205 | 236 | 258 |
|               | Decentralized heating | 61 | 70 | 89 | 103 | 113 |
|               | Total | 202 | 230 | 294 | 339 | 371 |
| B             | Central heating | 141 | 155 | 179 | 184 | 178 |
|               | Decentralized heating | 61 | 68 | 81 | 87 | 87 |
|               | Total | 202 | 222 | 260 | 271 | 265 |
| C             | Central heating | 141 | 163 | 217 | 260 | 295 |
|               | Decentralized heating | 61 | 66 | 74 | 72 | 65 |
|               | Total | 202 | 229 | 291 | 332 | 360 |
| D             | Central heating | 141 | 157 | 189 | 203 | 203 |
|               | Decentralized heating | 61 | 65 | 67 | 62 | 52 |
|               | Total | 202 | 222 | 256 | 265 | 256 |

3.2. Results
The calculation results of the four scenarios are shown in table 5. In the basic scenario A, the total heating energy consumption continues to rise, and the total energy consumption will reach 371 million tce in 2035. Scenario B brings the peak forward to 2030 by controlling energy intensity. Scenario C can save 11 million tce compared with A by changing the proportion of heating mode. In the ideal scenario D, the heating energy consumption in 2035 is 115 million tce less than that in A, and the peak of scenario D in 2030 is only 265 million tce.
4. Conclusion
According to the current development situation, the total energy consumption of heating increases year by year with the increase of urban building area, and will reach 371 million tce in 2035. But if the energy intensity and proportion of heating are adjusted, the total energy consumption of heating in northern China will peak in 2030, when the energy consumption will be only 265 million tce. Controlling the energy consumption intensity of heating has obvious energy saving effect on the energy consumption of heating in northern China. If only change the heating mode proportion, expand the scope of central heating, energy saving effect is not obvious. This paper proposes to strictly control the intensity of heating energy consumption, adjust the heating mode, expand the scope of central heating, and strive for an early peak of heating energy consumption.

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