Preliminary study on the influence of residents' central heating temperature on atmospheric environment

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Abstract. The cold weather in northern China requires a long heating period and uses central heating. The process of coal-fired heating has caused enormous pollution to the atmospheric environment. This paper starts from the point of reducing the central heating temperature of heating enterprises, and studies its impact on reducing pollutant emissions and mitigating air pollution. Think about whether it can alleviate the problem of air pollution in the northern winter by reducing the central heating temperature.

Keywords: Central heating; User design temperature; Air pollution; Environment.

1. The Research Background
According to the definition of the International Organization for Standardization (ISO), air pollution usually refers to the phenomenon that certain substances enter the atmosphere due to human activities or natural processes, causing them to exhibit sufficient concentration and thus endangering human comfort and the environment. In other words, as long as the quantity, nature and time of a certain substance are sufficient to affect humans or other living things and creatures, we can call it air pollutants; and the phenomenon caused by its existence is air pollution.

The cold weather in northern China requires a long heating period and uses central heating. Central heating is a city's public infrastructure that provides a stable source of heat for the city, optimizes the energy mix, and increases the penetration rate of central heating. At the same time, it also saves energy, reduces energy consumption, reduces urban pollution, and has made certain contributions to the protection of the ecological environment. Compared with decentralized heating, the central heating and heat utilization rate is high, the amount of coal burning is relatively reduced, and the emission of atmospheric pollutants is reduced. On the other hand, due to the large capacity of the boiler after the central heating, the chimney is reduced, and the combustion is relatively complete, so the pollutant emissions are reduced. At the same time, centralized heating is conditional on the use of high-efficiency dust removal equipment to reduce pollution emissions. However, as the centralized heating method in winter in China is still dominated by coal burning, the pollution index in the north of China is still high every heating season, and the air pollution problem in the north is still outstanding. In addition to generating a large amount of soot when burning fuel, carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxides, organic compounds and other substances are formed during the combustion process, which is an important culprit for air pollution. Environmentally-friendly dust-removing equipment is difficult to put into operation substantially. The smoke is directly discharged into the air after burning coal, which has a great impact on the atmosphere.
Taking the data of atmospheric pollutant emissions from a winter heating city in the north of 2015 to 2018 as an example, it can be seen from Table 1 that the problem of ambient air is still an important issue to be solved. The number of days with good ambient air quality showed a downward trend, and the average value of various atmospheric pollutants decreased slowly.

**Table 1.** The quality of the atmospheric environment in the city from 2015 to 2018.

|                                 | 2015      | 2016      | 2017      | 2018      |
|---------------------------------|-----------|-----------|-----------|-----------|
| Good days of ambient air quality(days) | 215       | 210       | 201       |           |
| Ambient air excellent rate(percentage) |           |           |           |           |
| Partial improvement rate | 58.9%     | 57.5%     | 55.8%     |           |
| Annual average value of sulfur dioxide($\mu$g/m$^3$) | 36ug/m3   | 29.2ug/m3 | 23ug/m3   | 18ug/m3   |
| Annual average value of nitrogen dioxide($\mu$g/m$^3$) | 48ug/m3   | 42.4ug/m3 | 45ug/m3   | 42ug/m3   |
| Annual average of inhalable particulate matter (PM10) ($\mu$g/m$^3$) | 141ug/m3  | 124ug/m3  | 114ug/m3  | 106ug/m3  |
| Average annual value of fine particles (PM2.5) ($\mu$g/m$^3$) | 76ug/m3   | 67.4ug/m3 | 60ug/m3   | 54ug/m3   |
| 24-hour average 95th percentile concentration of carbon monoxide($\mu$g/m$^3$) |           |           |           |           |
| 90th percentile concentration value of the maximum 8-hour moving average of ozone day($\mu$g/m$^3$) |           |           |           |           |
| City Urban Ambient Air Quality Index | 6.86      | 6.56      | 6.04      |           |
| Annual average value of precipitation pH in the city |           |           |           |           |

Table 2 reflects the year-on-year increase in atmospheric environmental quality in the city from 2015 to 2018. According to the data, it can be seen that the annual improvement rate of various atmospheric pollutants is relatively slow, and the annual improvement speed is weak and lacks breakthrough. For the north, winter heating is one of the important reasons for adding significant gas pollution. It is extremely urgent to reduce the pollutant emissions from central heating.

**Table 2.** The year-on-year increase in atmospheric environmental quality in the city from 2015 to 2018.

|                                 | 2015      | 2016      | 2017      | 2018      |
|---------------------------------|-----------|-----------|-----------|-----------|
| City's urban ambient air quality index improved year-on-year | 11.44%    | 5.5%      | 7.9%      |           |
| Sulfur dioxide improved year on year | 21.6%     | 20.7%     | 21.7%     |           |
| Nitrogen dioxide improved year on year | 10.28%    | -2.3%     | 6.7%      |           |
| Respirable particulate matter improved year on year | 11.4%     | 10.2%     | 7.0%      |           |
| Fine particulate matter improved year on year | 13.52%    | 10.4%     | 10.0%     |           |
| Ozone improvement | 0.98%     | -10.8%    | -0.5%     |           |
| Carbon monoxide improved year on year | 11.08%    | 16.7%     | 5.0%      |           |

In view of the serious air pollution problem in the northern region, in order to prevent the impact of central heating on air pollution, there are two main ideas. The first is to further promote the change of heating technology. At present, the heating company mainly uses the cogeneration unit of the power generation company as a heat source, and has continuously integrated the idea of changing heating technology into the production process. Secondly, the use of new energy to replace the old energy, the government is making efforts to promote the "coal to gas" process, but due to regional differences, high natural gas prices, low subsidy rate, etc., it is difficult for enterprises to truly implement "coal to gas".
The progress of the transformation is relatively slow. How to quickly and effectively alleviate the air pollution caused by central heating is a problem we must consider today.

Hygiene will use 12 degrees Celsius as the lower limit of the building thermal environment. According to the National Indoor Air Quality Standard (GB/18883-2002), the winter heating standard is 16 to 24 degrees Celsius. The indoor temperature meeting this standard is the comfortable indoor temperature. The temperature of central heating does not need to be too high. According to the actual experience of life, during the central heating in the north, many households have high heating temperatures. In winter, they even need to wear short sleeves at home. Some home heating temperatures can reach 27 or 28 degrees Celsius. Not only do you have to wear short sleeves and sandals, but you also need to open the windows frequently to dissipate heat. Such a phenomenon is undoubtedly a waste, and residents do not need such a high heating temperature, but they cannot adjust. This paper starts from the point of reducing the central heating temperature of heating enterprises, and studies its impact on reducing pollutant emissions and mitigating air pollution. Think about whether it can alleviate the problem of air pollution in the northern winter by reducing the central heating temperature.

2. Research Design

2.1. Sample and Data Source
At present, China's standard heating temperature is increased or decreased by 2 degrees Celsius at 18 degrees Celsius, and the user's room temperature design of heating enterprises is mainly at 18 degrees Celsius. This paper takes the data of a heating enterprise in the central part of the northern region as an example, and calculates the impact of one month on the atmospheric environment after the design temperature of the central heating user is reduced according to the enterprise data. The annual income and expenditure of the company is shown in Table 3, which is used for auxiliary analysis.

| Serial number | Income   | Expenditure |
|---------------|----------|-------------|
|               | project  |             | Cost amount (ten thousand yuan) | Remarks |
|               |          |             | Year 2011 | Year 2012 | Year 2013 | Year 2014 | Year 2015 | Year 2016 | Year 2017 | Year 2018 |
| 1             | income   | Hot fee     | 18200     | 21600     | 24200     | 26200     | 28600     | 31300     | 33200     | 37500     |
| 2             |          | Matching fee| 6900      | 7050      | 7100      | 7430      | 7320      | 7250      | 7380      | 7400      |
| 3             |          | Purchase of heat | 17360 | 19370 | 20960 | 22600 | 24200 | 26100 | 26700 | 29500 |
| 4             |          | Power fee   | 1820      | 2060      | 2200      | 2600      | 3000      | 3400      | 3600      | 4000      |
| 5             |          | Labor compensatio n | 750 | 800 | 900 | 1000 | 1100 | 1100 | 1200 | 1300 |
| 6             |          | Depreciation | 3060     | 3700      | 4100      | 4300      | 4600      | 4800      | 5200      | 5600      |

2.2. Calculation Direction
The design temperature reduction of heating users will affect air pollution prevention through direct and indirect ways. The direct approach is to reduce the heat demand by reducing the user's design temperature, thereby reducing pollutant emissions during the heat production process. As the demand for heat energy decreases, power plants that supply thermal energy to heating companies will reduce the supply of heat, thereby reducing a certain amount of pollutant emissions. If the central heating enterprise is used as a starting point to promote to a wider area, the design temperature reduction of heating users will have a broader impact on the prevention and control of atmospheric pollution. The indirect route means that the heating enterprise will reduce the cost of purchasing heat due to the reduction of the user's design temperature, and indirectly serve the pollution prevention and control on the premise of rational use of funds. The user-designed temperature reduction and reduced heat will bring preferential
treatment to the heating enterprise's own development. The company's purchase of heat will be reduced, and the cost savings can be used for purification equipment and heating system upgrades through government policies and regulations, etc., further promoting the transformation of heating enterprises. Based on this thinking, I designed the following calculation directions.

1. The impact on the environment. Heating companies will reduce the user's design temperature by one degree. How much pollutant emissions can be reduced by a power supply plant that supplies heating energy to a heating company in one month?
2. Promote to the entire northern region with the central heating enterprises in the north as the starting point. Calculate how the entire northern region will change to the atmospheric environment after the user's design temperature is lowered by one degree.
3. How much material consumption can be saved by one month's reduction? How much is the heating cost of the heating company reduced? What aspects of the company's savings in purchasing heat can be used to improve?

3. Model Construction and Variable Introduction

3.1. Variable Setting

\( \text{temp}_c \): Design ambient temperature.
\( \text{temp}_u \): User room temperature design.
\( r \): Building heat consumption index.
\( r_1 \): If the user's room temperature design is lowered by one degree, the heat consumption index is lowered.
\( s \): Heating company heating area, in units of 10,000 square meters.
\( h \): If the user design temperature is lowered by one degree, the heat can be reduced by one month.
\( \text{price}_h \): Hot price.
\( \text{price}_r \): Saved on the cost of purchasing hot money.
\( \text{profit}_c \): In the case of other expenses unchanged, the monthly profit increase. VAT rate is 10%.
\( C_{\text{so2}} \): Sulfur dioxide emissions, kg.
\( b \): The amount of fuel coal consumed, kg.
\( S_c \): Total sulfur content in the fuel, %.
\( \eta \): Sulfur dioxide removal rate (dust removal efficiency) of the desulfurization (denitration) (dust removal) device, %.
\( V_f \): Flue gas volume (dry), Nm\(^3\)/kg coal.
\( G_{\text{NOx}} \): NOx emissions, kg.
\( C_{\text{NOx}} \): Concentration of nitrogen oxides.
\( G_{\text{sd}} \): Soot emissions, kg.
\( a \): Dust content in coal.
\( G_{\text{fh}} \): Carbon content in soot.
\( d_{\text{fh}} \): The share of fly ash in the soot in the total amount of ash.

3.2. Research Model

This paper uses the following model for testing

\[
h = (s \times 10^4 \times r_1 \times 30 \times 24 \times 3600) \times \frac{1}{10^9}
\] (1)

The user design temperature is lowered by one degree, and the heat reduced in one month is: the original heating area is multiplied by ten to the fourth power and converted into square meters, and then multiplied by the user's room temperature design, the hourly heat consumption index is reduced, multiplied by 24 hours and 30 days, and the monthly room temperature is calculated. Reduced heat unit conversion multiplied by \(3600 \div 10^9\) to GJ.
The calculation formula for the emission of sulfur dioxide generated after coal combustion. The composition of sulfur in coal can be divided into combustible sulfur and non-combustible sulfur, and combustible sulfur accounts for about 80% of total sulfur.

\[ C_{SO2} = 2 \times 80\% \times b \times S_c \times (1 - \eta) \]  \hspace{1cm} (2)

\[ G_{NOX} = V_y \times 10^3 \times C_{NOX} \times 10^{-6} \times (1 - \eta) \]  \hspace{1cm} (3)

Formula for calculating the amount of nitrogen oxides emitted after coal combustion.

\[ G_{sd} = d_{fh} \times b \times a \times (1 - \eta) \times (1 - C_{fh}) \]  \hspace{1cm} (4)

Formula for calculating soot emissions.

\[ price_r = h \times price_h = (s \times 10^4 \times r_t \times 30 \times 24 \times 3600) \times price_h \div 10^9 \]  \hspace{1cm} (5)

The cost of the hot money purchase is: reduced heat multiplied by the heat price.

\[ profit_e = price_r - price_r \times 10% \div (1 - 10%) \]  \hspace{1cm} (6)

The increase in profit is: the reduction in the purchase cost of the hot fee minus the deductible input tax.

4. Empirical Results and Analysis

Take the central heat company in the Three North Region as an example, the heating area is 22 million square meters, the design ambient temperature is -6°C, the user room temperature is designed to 18 °C, and the building heat consumption index is 45W/m² per hour. When the room temperature is lowered by one degree, the heat consumption index is reduced by 1.88W/m² per hour. The amount of heat that can be saved in a month is 107,200 GJ, \[ (2200 \times 10^4 \times 1.88 \times 30 \times 24 \times 3600) \div 10^9 = 107,200 \text{ GJ}. \]

Percentage of heat loss reduction, which is the percentage reduction of pollutant emissions, and the percentage of heating intermediate coal consumption = 1.88/45 \approx 4.18\%. According to the formula for calculating the emission of sulfur dioxide generated after coal combustion, when there is no desulfurization facility, 1000 kg of coal produces 12.8 kg of sulfur dioxide, \[ 2 \times 80\% \times 1000 \times 0.8% \times 1 = 12.8 \text{ kg}. \] \( V_y \) is 9.68 Nm³/kg, and \( C_{NOX} \) is 500 mg/m³. When there is no denitrification facility, \( G_{NOX} \) is 4.84 kg, \[ 9.68 \times 10^3 \times 500 \times 10^{-6} \times 1 = 4.84 \text{ kg}. \] A takes 25%, \( C_{fh} \) takes 30%, \( d_{rh} \) takes 25%, and when the dust removal efficiency is 85%, \( G_{sd} \) is 13.39 kg, \[ 25\% \times 1000 \times 25\% \times (1 - 85\%)/(1 - 30\%) = 13.39 \text{ Kg}. \] The discharge of coal-fired pollutants is large. Reducing the heat demand by 4.18% can directly reduce pollutant emissions and bring huge benefits to the improvement of the atmospheric environment.

China has a vast territory and complex climatic conditions, which are divided into five climatic regions. The traditional heating areas mainly include 15 provinces and cities in the cold and cold regions, most of which are located in the northern region, accounting for 70% of the national land area, as shown in Figure 1. The population exceeds 40% of the country's total population. According to the data released by Zhiyan Consulting on China Industrial Information Network (Figure 2), as of 2016, China's heating area reached 7.387 billion square meters. This heating area contains a small amount of non-combustion coal heating such as natural gas heating, which is not considered here. The heating company's heating area is only 22 million square meters, reducing the user's room temperature design by one degree, saving 107,200 GJ heat in one month. Under the heating area of 7.387 billion square meters, if the user's room
temperature design is reduced by one degree, it can save about \( \frac{73.87}{0.22} \times 10.72 = 35.394 \) million GJ heat per month.

**Fig 1. Division of district heating districts in China.**

The hot price is calculated at 45 yuan/GJ, which can save the heat cost purchase cost of 4.824 million yuan, \( 107200 \times 45 = 4824000 \) yuan. The monthly profit increased by 4,835,500 yuan while other expenses remained unchanged, \( 4824000 - 4824000 \times 10\% \div (1 - 10\%) = 4,835,500 \) yuan. The increase in profits of heating companies due to the reduction of user design temperature is more conducive to the further construction and investment of environmental protection equipment, and the further expansion of energy conservation and emission reduction. According to the income and expenditure schedule of the enterprise, the main expenditure of the heating enterprise is the purchase price. Taking the four-month heating period as an example, The profit that can be increased by reducing the user's design temperature within one year is \( 438.55 \times 4 = 175.42 \) million yuan. According to the calculation formula of atmospheric pollutants, desulfurization, denitrification and dust removal equipment can effectively reduce the emission of atmospheric pollutants. With the support of certain
policies, enterprises will have more opportunities to use funds for the configuration of cleaning equipment to promote energy conservation and emission reduction.

5. Conclusion and Enlightenment
The research results show that heating companies have great benefits in down-regulating heating temperatures. The heating company's downward adjustment of heating temperature is of great significance to residents' lives, corporate transformation, and the atmospheric environment. For residents, lowering the heat saved by heating temperature will give more residents the opportunity to enjoy central heating, improve their quality of life and increase national happiness. Reduce the physical discomfort caused by excessive indoor temperature and improve human immunity. In the case of enterprises, the power and heat production and supply industries have developed rapidly, and their fixed asset investment has also shown a rapid growth trend. Especially since 2011, under the policy of encouraging and guiding private capital to enter municipal public utilities, the energy and power production and supply industries have increased their vitality, and the total investment in fixed assets has continued to increase substantially. As shown in Figure 3 and Figure 4. Lowering the heating temperature will reduce the cost of purchasing heat and promote the development of thermal enterprises. Under the guidance of national policies, it will help heating companies to adjust the capital structure and promote the transformation and upgrading of enterprises. In terms of the national environment, there are many heavy industries in the north. Due to the influence of winter climatic factors, pollutants are not easy to spread, and the problem of air pollution is more serious. Central heating relies mainly on burning coal. The combustion of coal produces a large amount of soot dust, which is even worse for air problems. Lowering the heating temperature will reduce the emission of atmospheric pollutants during the central heating process, creating new opportunities for environmental management and alleviating the air environment in the north.

![Graph](image.png)

**Fig 3.** 2010-2016 China's electricity and heat production and supply industry fixed assets investment.
Fig 4. 2010-2016 China's power and heat production and supply industry fixed asset investment growth rate.

There are still some unavoidable problems in the experiment. For example, the design environment temperature is -6 °C in the central region. In fact, China has a vast territory, large regional differences, and different design environment temperatures. In addition, in reality, there are also a few communities or units whose room temperature is lower than the monitoring data due to aging of heating equipment, and the residents feel that the heating temperature is too low. This reflects the current low heat utilization efficiency and high energy consumption of centralized heating systems in China. The next reform of central heating should also consider how to solve the heat loss caused by local overheating caused by improper system design and improper regulation, effectively reducing the imbalance of radiator area, local heat source in the building, and uneven system flow. Improve the heat utilization efficiency of the central heating system. The use of new energy-saving new methods, the use of automatic control devices to freely adjust comfort, according to heat metering charges, etc., will become the main development trend of urban central heating. Improve the more complete heating system and create favorable conditions for temperature adjustment.

In addition to the state, heating companies should also think about this. With the continuous deepening and strengthening of the market economic system reform, the relationship between the reform of the energy industry and environmental protection is getting closer and closer, and to some extent, the traditional energy coal-fired power plants are in a situation where both opportunities and challenges coexist. Under such circumstances, if heating enterprises want to survive and develop in the fierce market competition, they must actively formulate and improve the internal management mechanism of enterprises, strengthen environmental protection work and financial management, and ensure the economic and social benefits of enterprises are doubled. Enterprises can improve the accounting mechanism, build a more detailed enterprise information system through accounting and computerization, and provide more specific information for the reform. Enterprises should also take the initiative to purchase environmental protection equipment, strengthen transformation and upgrading, and promote the healthy and stable development of heating enterprises.

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