Quantification and scenario analysis of CO_2 emissions from the central heating supply system in China from 2006 to 2025

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Abstract

Policies associated with the central heating supply system affect the livelihoods of people in China. With the extensive consumption of energy for central heating, large quantities of CO_2 emissions are produced each year. Coal-fired heating boiler plants are the primary source of emissions; however, thermal power plants are becoming much more prevalent, and gas-fired heating boiler plants remain uncommon. This study quantified the amount of CO_2 emitted from the central heating supply system in China using a mass balance method with updated emission factors from the IPCC. Emissions increased from 189.04 Tg to 319.39 Tg between 2006 and 2015. From a spatial perspective, regions with larger central heating areas, durations and coverages produced more CO_2 emissions. The central heating method depends on the level of electric power consumption, policies and regulations, and resource reserves at the local scale. Compared with the use of only coal-fired heating boiler plants to provide central heating, using thermal power plants and gas-fired heating boiler plants reduced CO_2 emissions by 98.19 Tg in 2015 in China. A comparison of the CO_2 emissions under various central heating scenarios showed that emissions will be 520.97 Tg, 308.79 Tg and 191.86 Tg for business as usual, positive and optimal scenarios through 2025, respectively. China has acknowledged the considerable potential for reducing central heating and will make efforts to pursue improved heating strategies in the future.

Keywords: Climate change, CO_2 emissions, Central heating, China

Introduction

Because of rapid economic development, China has the highest greenhouse gas emissions worldwide from an energy consumption perspective. Without mitigation, China's CO_2 emissions are expected to increase by more than 50% in the next decade [1]. In 2015, China pledged to reduce its CO_2 emissions per unit of GDP by 60% to 65% by 2030 compared with the level in 2005. In addition, China has embraced the Paris Agreement on climate change and has promised to achieve the commitment made in this agreement. Verifying, quantifying, and reducing carbon emissions from all sectors represent the greatest current challenges faced by China.

The central heating supply system is an important policy consideration that affects people's livelihoods in China. Because of the extreme cold and long winters in northern China, a central heating supply policy has been implemented in cities north of the Huai River, which divides China into north and south regions [2, 3]. This policy provides central heating in these regions for 120 to 180 days each year based on the local temperature. Heating is considered an important factor in energy consumption [4]. Central heating consumption accounts for nearly 65% of building energy consumption and 20.6% of total energy consumption [5]. In the north-central regions of China, up to 85% of heating is supplied by central heating, and this heat supply is mainly produced by burning coal [6]. A substantial reduction in CO_2 emissions can be achieved by replacing fossil fuels and electricity [7]. Central heating in China is mainly supplied by heating boiler plants (HBPs) and by cogeneration from thermal power plants (TPPs). HBPs represent the traditional method of generating a central heating supply. Based on the energy type, HBPs can be divided into coal-fired heating boiler plants (CHBPs) and gas-fired heating boiler plants (GHBPs). CHBPs represent the main source of the central heating supply. The advantages of CHBPs are the associated low cost, low investment, and short construction period. However, because the efficiency of energy conversion is low, CHBPs substantially contribute to environmental pollution [8]. Because of their high efficiency and low pollution output, GHBPs have been promoted as an alternative to CHBPs. Targeting the various gas utilization fields noted in the "Natural Gas Utilization Policy" by the National Development and Reform Commission of China (NDRC) [9], China is working to replace coal with natural gas for central heating in cities. Compared with HBPs, TTPs offer the advantages of safer operation, environmental protection, and low production costs [8]. TPPs have also been promoted as replacements for the scattered heating network composed of small inefficient CHBP facilities in China. China is now in a period of strategic opportunity for heating supply reform and development, and determining the CO_2 emissions from the heating supply sector would play an important role in future city planning and greenhouse gas mitigation policymaking.

A considerable amount of research has been performed on greenhouse gas emissions and carbon reduction in China in recent years [10-20]. This research has thoroughly quantified and analysed regional disparities. However, because of the limited availability of central heating activity data and relatively lagged management of greenhouse gases, limited research has been conducted regarding CO_2 emissions from central heating supplies. Liu [21] conducted a thermodynamic analysis of various heating systems related to central heating and the effects of heating parameters on net heating; however, a deficiency was observed in this research. Specifically, Liu did not couple the CO_2 emissions from central heating with heating policy changes. Liu [22] calculated the specific CO_2 emissions of four Chinese megacities and presented the features, trajectories and driving forces of all sectors, including the heating supply. However, Liu did not identify and analyse the CO_2 emissions from the central heating supply because the heating supply was considered a combination of the industrial heating supply and central heating supply. Chen [23] analysed the current situation and problems pertaining to central heating and evaluated the potential for reducing energy consumption and CO_2 emissions by implementing heat pump heating. Chen proposed that heat pump heating could replace central heating and help achieve greater energy savings and emission reduction goals. Although Chen's novel approach is worthy of evaluation, replacing central heating is not a valid scheme based on the current scenario in China and the associated economic costs of such a project. Overall, improving and reforming the efficiency of central heating remain problems in present-day China that require solutions. Zhang [24] investigated the technical feasibility and economical applicability of a low-temperature air source heat pump heating mode. Compared with a conventional heating system, the low-temperature air source heat pump heating mode had lower CO_2 emissions. However, considering the current state of central heating in China, it is difficult to replace HBPs with low-temperature air source heat pump heating mode at a large scale. Pang [25] calculated the scale of air pollutant abatement effects by replacing coal with natural gas for central heating in 15 major Chinese cities receiving heat in 2010 and showed that significant emission reduction effects can be achieved by converting the fuel used in central heating systems from coal to natural gas. However, because of the limitations of the research sample and research duration, Pang's research did not represent the spatial and temporal heterogeneity throughout the entire central heating region. Wang [26] performed brief calculations and analyses of CO_2 emissions throughout the entire Harbin area, and Jin [27] calculated the CO_2 emissions from different types of heating methods in Beijing. These studies contributed to defining the relative emission factors used to calculate the

CO_2 emissions from the heating supply, although the researchers have not extended the results to the entire central heating region. Li [28] described the development status and trends in district heating in China and summarized the control strategy and concrete measures for energy savings and emission reductions in the district heating system. Li then summarized the heat production, heat transfer and heat use processes; conducted a detailed analysis of central heating; and provided scientific advice for policymakers. However, Li primarily focused on energy consumption and the heat cycle but did not properly address the mitigation of CO_2 emissions. To date, a complete inventory of central heating CO_2 emissions is not available, and considerable uncertainty remains regarding the future of central heating. CO_2 emissions in China have maintained steady growth over the past decade [29-31]. Moreover, the emissions from energy activities in China are expected to peak in approximately 2025 [32]. In addition, since the eleventh five-year plan was established in 2005 [33], the Chinese government has invested in reducing energy consumption and CO_2 emissions from the central heating supply system. Therefore, analysing the CO_2 emissions from the central heating supply system from 2006 to 2025 is of great significance for assessing the characteristics of CO_2 emissions and the peak of CO_2 emissions in China. Therefore, the objectives of this study were as follows:

1. Quantify the CO_2 emissions from the central heating supply system in

China from 2006 to 2015;

2. Analyse the characteristics of the central heating supply system in China and the related changes across different regions;
3. Assess the future emission situation via scenario analysis through 2025 and provide scientifically sound information and suggestions for policymakers.

Methods and Data

1. Calculation of CO_2 emissions from the central heating supply system from 2006 to 2015

In this study, CO_2 emissions were calculated using the mass balance method suggested by the Intergovernmental Panel on Climate Change (IPCC) [34, 35] and NDRC [36, 37].

$E=\sum\sum\sum(\text{Activity data}_{ijk}\times\text{Emission factor}_{ijk})$

where i is the fuel type, j is the sector, and k is the technology type.

In this study, the CO_2 emissions from the central heating supply system were calculated by the following formula:

$E=E_{tpp}+E_{chbp}+E_{ghbp}=Q_{tpp}\times EF_{rc}+Q_{hbp}\times EF_{rc}\times(1\text{-}R)+Q_{ghbp}\times EF_{ng}\times R$

where E represents the CO_2 emissions from the central heating supply system, including E_{tpp} (TPPs), E_{chbp} (CHBPs) and E_{ghbp} (GHBPs), and EF_{rc} and EF_{ng} are the emission factors for raw coal and natural gas, respectively (Table 1).

Central Heating Supply Type	Energy Type	Emission Factors (Tg $CO_2/10\times10^{18}$ J)
Thermal Power Plant	Raw coal	96.51
Coal-Fired Heat Supply Boiler Plant	Raw coal	96.51
Gas-Fired Heat Supply Boiler Plant	Natural gas	56.17

Table 1: Parameters used to calculate the CO_2 emissions for various heating supply types from 2006 to 2015 in China

The emission factors used here were provided by Liu [38, 39], and they are assumed to be much more accurate than the default values of the IPCC and NDRC. Q_{tpp}, Q_{hbp} and Q_{ghbp} represent the consumption of energy from TPPs, HBPs and GHBPs, respectively. These values were provided by the China Urban-Rural Construction Statistical Yearbook [40]. R represents the percentage of natural gas usage in the central heating supply. Because central heating supply is a part of the overall heating supply, it is difficult to calculate the energy consumption in the central heating supply system separately based on the data available. Therefore, it is impossible to directly obtain the gas consumption of the central heating system over a long period and the full spatial extent of China. The government of China issued a series of policies to promote natural gas heating in recent years. Due to the consistency of policy implementation, the percentage of gas usage by the central heating supply system often matches that of the overall heating supply system. Thus, in this study, the percentage of natural gas usage in the overall heating supply system is used in the calculations. This value was calculated from the energy balance tables [41].

The research range included 10 provinces (Hebei, Shanxi, Liaoning, Jilin, Heilongjiang, Shandong, Henan, Shannxi, Gansu and Qinghai), 3 autonomous regions (Inner Mongolia, Ningxia and Xinjiang) and 2 municipalities (Beijing and Tianjin) in China. These regions were considered the main central heating supply areas. The data were collected from the China Statistical Yearbooks [42], China Energy Statistical Yearbooks [41] and China Urban-Rural Construction Statistical Yearbook [40]. The data used in this study, including energy consumed by TPPs and HBPs, were primarily collected from statistical yearbooks, which have an inherent degree of uncertainty. For example, statistical energy data from China have uncertainties of 5-10% [43]. Furthermore, data scarcity issues, such as that for the percentage of natural gas usage in the central heating supply, the compilation and updating of CO_2 emission inventories. In addition, emission factors are associated with scientific uncertainty and must be updated via experimental analyses and interdisciplinary studies [38].

2. Scenario analysis of future CO_2 emissions from the central heating supply system in China

Based on the present situation, we assumed three different CO_2 emission reduction scenarios (business as usual, positive and optimal) regarding the central heating supply system through 2025. These scenarios were chosen based on various parameters, including the “TPP efficiency”, “GHBP efficiency”, “CHBP efficiency”, “transport efficiency”, “TPP proportion”, “GHBP proportion”, “thermal loss in buildings” and “charging method” (Table 2). The efficiency of TPPs, GHBPs and CHBPs directly determines the heating consumption [28]; therefore, it is of significance in determining the CO_2 emissions from the central heating supply system. During the process of pipeline heat transport, heat loss occurs to various degrees. Because the transport efficiency can be improved in all regions of China, we set the "transport efficiency" as one of the parameter. There are significant difference among the heating efficiencies and energy types of TPPs, GHBPs and CHBPs, and the proportions of TPPs, GHBPs and CHBPs have recently changed in China [44, 45]. Therefore, the proportions of TPPs and GHBPs are key factors that influence CO_2 emissions from the central heating supply system in China. Thermal loss in buildings has resulted in considerable energy waste in China [28]. With improvements in building technology and the implementation of green building strategies, the thermal loss in buildings could be reduced over a large geographic portion of China. In addition, charging methods notably affect heat consumption. From experience in northern European countries, changing from an area-based charge to a metering charge will reduce heating consumption by 20% to 30% [46]. Therefore, we consider the “charging method” as one of the parameters. The future central heating demand was calculated from the estimated consumption results presented by Li [28].

	TPP Efficiency	GHBP Efficiency	CHBP Efficiency	Transport Efficiency	TPP Proportion	GHBP Proportion	Thermal Loss in Buildings	Charging Method
Business as usual	90%	90%	60%	70%	50%	4%	Same as the current	Same as the current
Positive	90%	90%	70%	80%	60%	12%	10% lower	Partial metering charge
Optimal	90%	90%	80%	90%	70%	15%	20% lower	Full metering charge

Table 2: Parameter values used in various central heating supply scenarios in China through 2025. TPP represents the emissions from thermal power plants; CHBP represents the emissions from coal-fired heat boilers; and GHBP represents the emissions from gas-fired heat boiler plants.

The “TPP efficiency” and “GHBP efficiency” are considered to be 90% in China based on recently developed technology [9, 44]. The “CHBP efficiency” in China is currently approximately 60% [28]. With improvements in technology and management and the demolition of medium and small boilers, the average boiler efficiency will be greatly improved in the positive and optimal scenarios. We set the business as usual coal-fired boiler efficiency at 60%, which is the same as the current value, the positive coal-fired boiler efficiency at 70% and the optimal coal-fired boiler efficiency at 80% in 2025. The “transport efficiency” could theoretically reach 90%, although in reality, the transport efficiency in China is approximately 70% based on the current technology and management [28]. We set the business as usual transport efficiency to 70%, which is the same as current value, the positive transport efficiency to 80% and the optimal transport efficiency to 90% in 2025. The current “TPP proportion” is nearly 50% in China. According to the “management method of TPP” [44], China is trying to improve this percentage to 60% in northern large- to medium-sized cities and cover all counties with populations over 2 million. Therefore, we set the business as usual TPP proportion to 50%, which is the same as the current proportion, the positive TPP proportion to 60% and the optimal TPP proportion to 70% in 2025. The current “GHBP proportion” is 4% in China. As reported by the NDRC [45], China is aiming to raise the contribution of natural gas to the fuel mix to 10% by 2020 and 15% by 2030. Therefore, we set the business as usual GHBP proportion to 4%, which is the same as the current proportion, the positive GHBP proportion to 12% and the optimal GHBP proportion to 15% in 2025. The “thermal loss in buildings” in China is currently approximately 3 times higher than that in developed countries with similar climate conditions [28]. We set the business as usual thermal loss in buildings to the current value, the positive thermal loss in buildings to 10% lower than the current value and the optimal thermal loss in buildings to 20% lower than the current value in 2025. The current “charging method” of central heating is area-based charging in China. An experiment by the Beijing District Heating Group showed that central heating consumption using a metering charge is 15% less than that derived from an area-based charge [47]. Additionally, an experiment in Jilin by the Jilin Water Group Corporation showed that metering charges produced heat consumption savings of 28% in residential zones [48]. We set the business as usual charging method to the current heating allocation approach based on the area; the positive charging method to partial metering charging, which will reduce consumption by 10%; and the optimal charging method to full metering charging, which will reduce consumption by 20% in 2025.

Results and Discussion

1. CO_2 emissions from the central heating supply system in China from 2006 to 2015

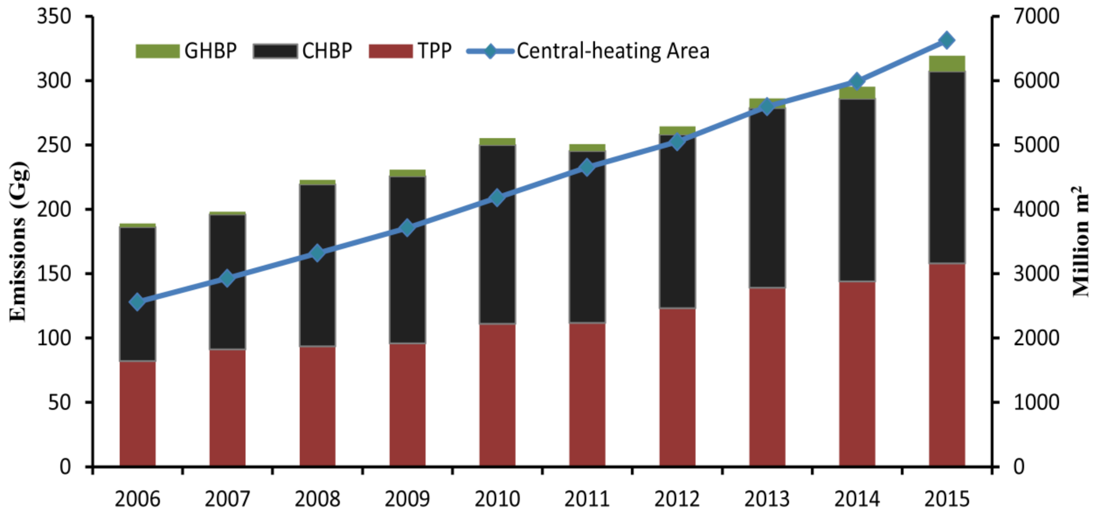

Figure 1: CO_2 emissions from the central heating supply system in China from 2006 to 2015. GHBP represents the emissions from gas-fired heat boiler plants; CHBP represents the emissions from coal-fired heat boilers; and TPP represents the emissions from thermal power plants.

Our results (Figure 1) show that CO_2 emissions from the central heating supply system in China increased from 189.04 Tg to 319.39 Tg from 2006 to 2015, with an annual average increase of 13.04 Tg. Compared with the total average energy consumption over the past decade [49], emissions from the central heating supply system generally remained at a level of 3%. With the development of urban construction in China, the central heating area also rapidly increased from 2561.31 million m^2 to 6626.73 million m^2, which is an annual average growth of 406.54 million m^2. Residential areas are the main central heating areas, and these areas increased from 1852.24 million m^2 to 4920.12 million m^2, with an average annual increase of 306.79 m^2.

Regarding the central heating sources, HBPs produced more than half of the emissions. CHBPs represent the main source of emissions; however, the scale of GHBPs is continuously increasing. Because of the high utilization efficiency of TPPs, China is consistently promoting TPPs as an alternative to small-scale CHBP. The proportion of emissions from TPPs gradually increased from 42% to 49%. With respect to the central heating energy types, emissions from coal are dominant because of the enormous usage and high emission factors. Although natural gas is far greener than coal, a limited amount of natural gas is used in China because of the relative lack of production and low economic benefits. With the development of a "Natural Gas Utilization Policy" [9] and economic growth in China, the usage of centrally supplied natural gas in China increased from 2% to 4% and was projected to continue increasing over the next decade.

2. Spatial distribution of CO_2 emissions from the central heating supply system of China in 2015

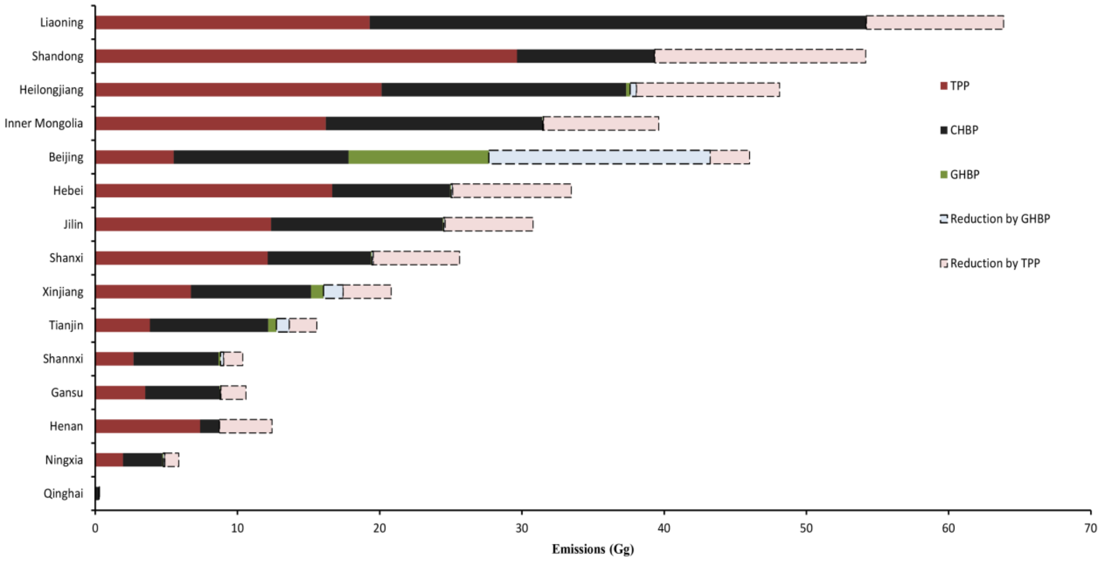

Figure 2: CO_2 emissions from the central heating supply system in all central heating regions of China in 2015. TPP represents the emissions from thermal power plants; CHBP represents the emissions from coal-fired heat boilers; and GHBP represents the emissions from gas-fired heat boiler plants. "Reduction by GHBP" is the CO_2 reduction obtained using GHBPs to replace CHBPs. "Reduction by TPP" is the CO_2 reduction obtained using TPPs to replace CHBPs.

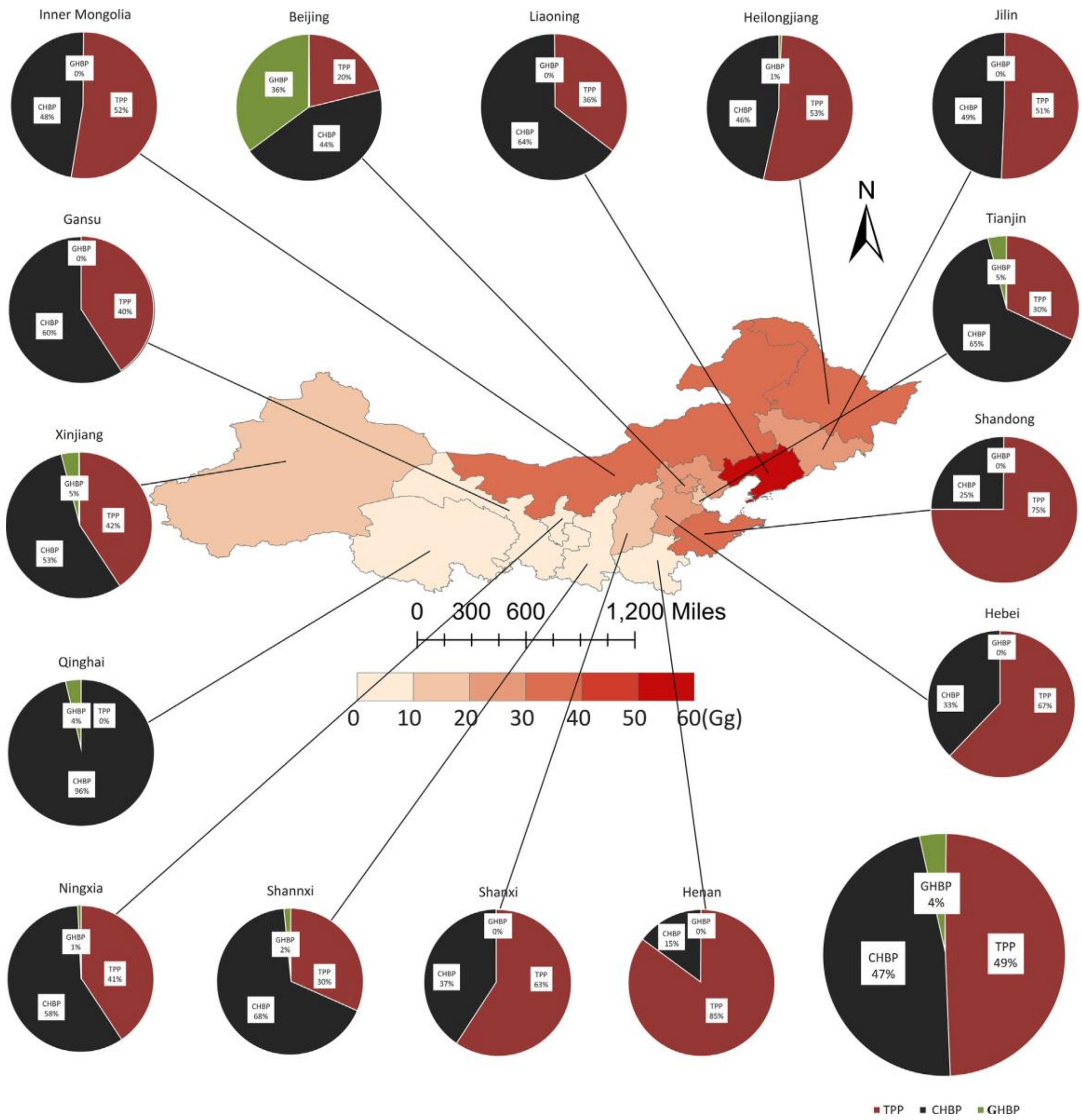

Figure 3: Spatial map of CO_2 emissions from the central heating supply system. The pie charts show the proportions of emissions from TPPs, CHBPs and GHBPs in all central heating regions of China in 2015. TPP represents the emissions from thermal power plants; CHBP represents the emissions from coal-fires heat boilers; and GHBP represents the emissions from gas-fired heat boiler plants.

In 2015 (Figures 2 and 3), Liaoning, Shandong and Heilongjiang were the three regions with the greatest emissions at 54.19 Tg, 39.32 Tg, and 37.61 Tg, respectively. Conversely, Henan, Ningxia and Qinghai were the three regions with the lowest emissions (0.27 Tg, 4.79 Tg and 8.73 Tg respectively), and these trends were mainly related to the central heating supply area, duration and coverage. Additionally, colder regions require longer durations of central heating. For example, Liaoning is offered central heating for 180 days, and Henan is offered central heating for only 120 days. In addition, the central heating coverage is determined by the development and urbanization level of the region; therefore, considerable variance in the emission quantities are observed between developed regions (Beijing and Shandong) and less developed regions (Qinghai and Ningxia). Overall, the regions with large heating supply areas, durations and coverages have higher heating demands and more heating facilities, which lead to more CO_2 emissions from the central heating supply system, and vice versa. In the top three emission regions (Liaoning, Shandong and Heilongjiang), central heating is supplied for all cities; the average heating duration is over 150 days; and the heating areas of the regions are 1045.43 million m^2, 901.50 million m^2 and 624.57 million m^2, respectively. Thus, these regions are the three largest heating areas in China.

A comparison of the CO_2 emissions from the different heating supply methods shows that TPPs are dominant in Henan, Shandong and Hebei, whereas HBPs are dominant in Qinghai, Beijing and Tianjin. These differences are related to electric power consumption, which varies significantly across all regions of China. As reported in the China Energy Statistical Yearbooks [41], for all the central heating regions in 2015, the regions with more than 500 billion kilowatts of consumption included Shandong and Hebei; the regions with more than 200 billion kilowatts included Henan, Inner Mongolia and Xinjiang; and the regions with less than 100 billion kilowatts included Beijing, Ningxia, Heilongjiang, Tianjin, Qinghai and Jilin. The emissions from TPPs were generally equivalent to those from electric power consumption. In general, most high consumption regions, such as Shandong, have abundant electrical power; therefore, a TPP can be efficiently and easily built. However, in low electrical power consumption regions, such as Qinghai, electrical power is not abundant, and the supply cannot be easily increased; therefore, these regions have long used HBPs to provide central heating.

Considering the central heating fuel type, because natural gas accounts for a low proportion of energy consumption in China, CO_2 emissions from GHBPs are only notably observed in Beijing, Tianjin and Xinjiang. These three regions account for more than 90% of the emissions from GHBPs throughout China. Xinjiang is the richest region in petroleum and natural gas resources, and the policies and measures for natural gas usage in the region are extensive and mature compared with those in other regions. Beijing is a developed megacity and the capital of China; therefore, the "Natural Gas Utilization Policy" was started in Beijing, and coal-fired boilers cannot be used to provide heating. Moreover, the use of natural gas-fired boilers and electrical power are encouraged, which is similar to the case in Tianjin.

The high thermal efficiencies of TPPs and GHBPs and the low emission factors of natural gas led to a 98.19 Tg reduction in CO_2 emissions in 2015 compared with the use of only CHBPs to provide central heating. The emission reductions for TPPs and GHBPs were 79.03 Tg and 19.16 Tg, respectively. The specific reductions in all regions widely varied. Taking Beijing as example, the 18.33 Tg reduction is remarkable and mostly derived from GHBPs. The reduction in Shandong is also significant (14.85 Tg), and it is mainly attributed to TPPs. Additionally, several regions, such as Ningxia and Gansu, exhibited a limited reduction potential because of the dominance of CHBPs.

3. Scenario analysis of various future CO_2 emissions from the central heating supply system in China

As previously noted, the central heating supply system is a potential sector for extensive CO_2 emission reductions in China. The government has observed this potential, introduced a series of policies, such as the "Management Method for Combined Heat and Power" policy [44], and provided subsidies for fuel switching [50]. Certain policy suggestions are provided for each region [51, 52]. According to the technological development and relevant policies formulated by the Chinese government, we created three different scenarios (business as usual, positive and optimal) to analyse the future CO_2 emissions from the central heating supply system [9, 28, 44-46].

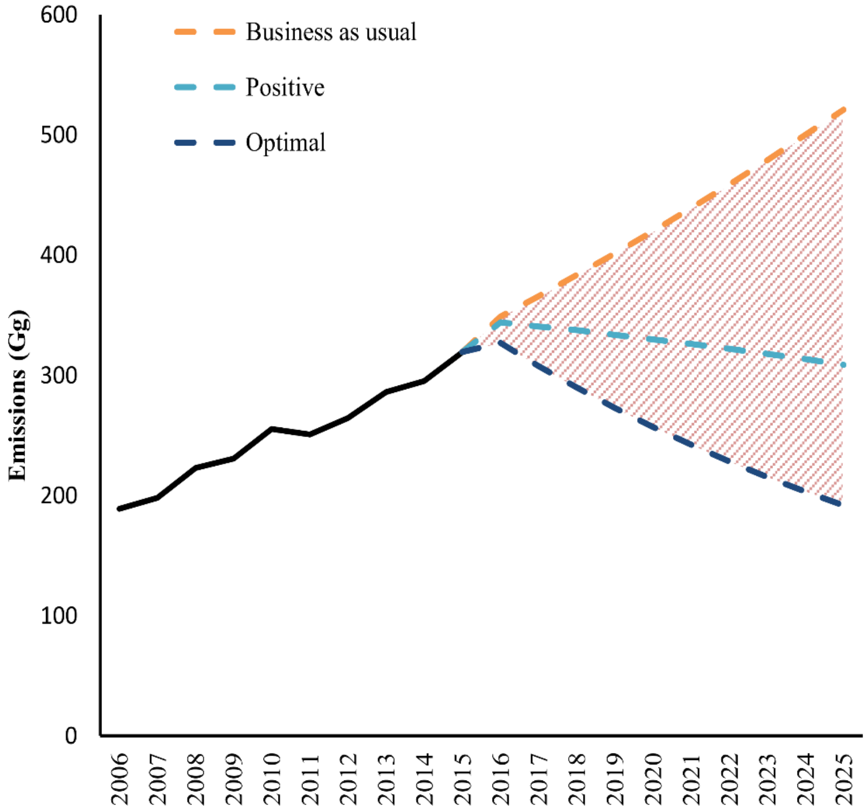

Figure 4: CO_2 emissions from the central heating supply system under different scenarios through 2025. The business as usual, positive and optimal scenarios are shown. The black solid line represents the emissions from 2006 to 2015. The pink area is the gap among all scenarios.

Our results (Figure 4) show that CO_2 emissions in 2025 will be 520.97 Tg, 308.79 Tg and 191.86 Tg under the business as usual, positive and optimal scenarios, respectively. The reduction observed between the business as usual and optimal scenarios is 329.11 Tg, which is greater than the total CO_2 central heating emissions in 2015. If the rate of change is stable, then the cumulative reduction gap will be 1781.83 Tg. In the positive scenario, the 212.18 Tg reduction is also notable, and the cumulative reduction is 1043.94 Tg. Under the business as usual scenario, the efficiencies of CHBPs and transport will be relatively low, and CHBPs will remain the main component of the heating system. Additionally, the thermal loss in buildings and charging method will remain the same. Therefore, the CO_2 emissions from the central heating supply system will rapidly increase, and the emissions in 2025 will be 63% higher than those in 2015. Under the positive scenario, the efficiencies of CHBPs and transport will gradually improve, and the proportions of TPPs and GHBPs will steadily increase. Moreover, the thermal loss in buildings will be 10% lower than the current value, and the charging method will shift to partial metering charging. Therefore, the CO_2 emissions will gradually decrease after a short initial increase. Specifically, the emissions in 2025 will be 3% lower than those in 2015. Under the optimal scenario, the efficiencies of CHBPs and transport will significantly improve, and the proportions of TPPs and GHBPs will be over 85%. Additionally, the thermal loss in buildings will be 20% less than the current value, and the metering charging method will be fully implemented. The emissions in 2025 will rapidly decrease to a level 40% lower than that in 2015. With the massive carbon reduction gap, the Chinese government must implement a positive or optimal central heating scenario. China can achieve this goal by improving the efficiencies of CHBPs and transport, increasing the proportions of TPPs and GHBPs, and reducing heating consumption by decreasing the thermal loss in buildings and adjusting the charging method from an area-based approach to metering.

Conclusions

With the improvement in living standards in China, the central heating area and heating consumption have greatly increased, and CO_2 emissions have rapidly intensified. The central heating area increased from 2561.31 million m^2 to 6626.73 million m^2 from 2006 to 2015, and CO_2 emissions from the central heating supply system in China increased from 189.04 Tg to 319.39 Tg. CHBPs have been the main source of emissions over the past decade. Additionally, TPPs have become more prevalent, and GHBPs account for a small proportion of plants. Across all central heating regions, the regions with high central heating supply areas, durations and coverages emit more CO_2. In addition, the regions with higher electrical power consumption exhibited greater emissions from TPPs. Only Beijing, Tianjin and Xinjiang produced observable emissions from GHBPs because of the limitations associated with policies and storage. Most regions are still dominated by CHBPs. A comparison of CO_2 emissions under various central heating scenarios showed that the emissions would be 520.97 Tg, 308.79 Tg and 191.86 Tg for the business as usual, positive and optimal scenarios through 2025, respectively.

Clearly, a considerable CO_2 reduction gap is observed in China, and this gap must be improved. For adequate heating and clean development, the government must improve the CHBP efficiency, use large boilers to replace small boilers and accelerate the planned phase out of boilers. The government also needs to increase their investments and subsidies to ensure that CHBPs are replaced by TPPs and GHBPs. Moreover, China should create cost-effective sources of renewable energy as an alternative for fuel energy via technology breakthroughs. Improving the transition efficiency, reducing the thermal loss in buildings via technical innovations, and reaching the heating levels of developed countries will dramatically reduce the central heating demand. Additionally, changing the charging method from an area-based approach to metering and improving the awareness of residents regarding reduction strategies are important priorities in China.

Acknowledgements

This study was financially supported by the National Key Research and Development Program of China (2016YFC0501804, 2016YFC0500203), the National Natural Science Foundation of China (41571081), the QianRen Program, and a Natural Sciences and Engineering Research Council of Canada (NSERC) Discover Grant.

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