ANALYSIS OF DRIVING FACTORS OF CARBON EMISSIONS IN RESOURCE-BASED CITIES: A CASE STUDY OF HANDAN, CHINA

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Abstract. Cities are pivotal in economic development and carbon emissions, with resource-based cities exhibiting heightened reliance on fossil fuels and elevated emissions. Analyzing emission drivers in such cities is critical for low-carbon transitions. This study investigates Handan City, China (2010–2022), quantifying regional carbon emissions across sectors and employing the Logarithmic Mean Divisia Index (LMDI) to identify key drivers. Results reveal three emission phases: fluctuating growth (2010–2014), sustained decline (2015–2019), and surge stabilization (2020–2022). Energy activities mainly involving energy production and processing, fossil fuel combustion, coal mining and post-mining activities dominated emissions (76.8–82.3% of total). Decomposition analysis demonstrates that cumulative drivers increased emissions by 42.7% compared to 2010. The per capita GDP effect (+75.4%) emerged as the primary growth driver, while industrial restructuring (-24.3%) served as the chief inhibitor. Energy intensity reductions (-23.4%) and fuel mix adjustments (-5.8%) exerted supplementary mitigating effects. These findings highlight the tension between economic expansion and emission control in resource-dependent cities. The study proposes targeted strategies including industrial diversification, energy efficiency enhancement, and clean energy transition, providing actionable insights for low-carbon transition strategies in comparable urban contexts.
Keywords: *carbon emissions, LMDI (Logarithmic Mean Divisia Index) model, factor analysis, urban energy consumption, sustainable development*

Introduction

Climate change has emerged as a major environmental challenge over the past 50 years due to dramatic changes in global temperatures (Schleussner et al., 2016). China, the biggest carbon emitter in the world, has pledged to reach carbon neutrality by 2060 and a carbon peak by 2030 (Wang et al., 2021). Cities, as the hubs of economic development and modern socio-economic activities, have become the main drivers of energy consumption and greenhouse gas emissions (Pichler et al., 2017). As a developing country, China is still in the process of urbanization, and the conflict between the increasing energy demand driven by economic growth and the pursuit of low-carbon development has become a reality (Liu et al., 2022). Simultaneously, low-carbon cities are essential to sustainable urban development, which poses new requirements for urban

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development in terms of urban management, urban development models, and greenhouse gas emissions (Zhang et al., 2022).

Resource-based cities refer to those that achieve economic development through the exploitation and processing of local natural resources, by mainly mining and high-energy-consuming industries (Yu et al., 2019). In the context of urban sustainable development, the development of natural resources should not only meet the needs of economic and social development but also ensure the coordination of the environment and ecology (Li et al., 2020). Under the guidance of the current "dual-carbon target," resource-based cities have excessive carbon emissions as a result of their highly polluting, energy-intensive, and intensive businesses (Liao et al., 2022). Currently, China's economic development levels and energy consumption are still linked, and resource-based cities encounter a number of social difficulties during the transformation process (Wei et al., 2020). Analyzing the traits of resource-based cities' carbon emissions, identifying the driving forces behind their carbon emissions, and attaining low-carbon development and urban energy transformation are essential for China to fulfill the "dual-carbon" target on time (Dong et al., 2007; Ruan et al., 2020; Li et al., 2021). At present, numerous researchers have conducted extensive research on the driving and influencing factors of urban carbon emissions, using models such as the LMDI model (Ang et al., 2015), Kaya identity (Duro et al., 2006), Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model (York et al., 2003), Propensity Score Matching–Difference in Differences (PSM-DID) model (Fan et al., 2021), and Autoregressive Distributed Lag (ARDL) model (Rauf et al., 2018), which decompose multiple influencing factors. Each model has its own advantages. Among them, the LMDI model can consider a variety of influencing factors and effectively address the issue of the decomposition residual term in exponential models. Therefore, it is among the best models for examining the variables that affect carbon emissions in cities.

Handan, a typical resource-based industrial city in northern China. Numerous types of minerals are abundant in the city's mineral resources. It is one of China's renowned coking coal and high-grade iron ore production areas, earning the titles of "coal capital" and "steel city." Its pillar industries mainly include the coal and steel industries, which rely on mineral resources. The 2022 Handan Municipal Government Work Report states that 69.6% of the above-scale enterprises were made up of the added value of the six high-energy-consuming sectors. As non-renewable natural resources, mineral resources are essential to Handan City's industrialization and economic growth. But since China's economic growth model has changed and the "dual-carbon target" is basic criteria have been suggested, new issues have arisen for the conventional regional development model, industrial structure, and energy consumption (Zhang et al., 2024). Thus, the goal of this study is to give a reference for the low-carbon development of comparable resource-based communities by analyzing the elements that drive carbon emissions using Handan City as an example.

Research methods

Carbon emission accounting methods

This study adopts the accounting method outlined in the "Provincial Greenhouse Gas Inventory Compilation Guide (Trial)" issued by the national center for climate change strategy and international cooperation (NCSC) (2020) to calculate the carbon emissions of four sectors in Handan City: energy activities, industrial production processes,

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agricultural activities, and waste treatment. Energy activities include energy production and processing conversion, fossil fuel combustion, coal mining and post-mining activities. Industrial production mainly includes emissions during the production of materials such as steel, cement, and lime. Agricultural activities include methane emissions from rice fields, animal intestinal fermentation, animal manure management, nitrous oxide emissions from agricultural land, etc. Waste treatment includes wastewater treatment and solid waste treatment emissions.

For energy activities, the sectoral method described in the Provincial Greenhouse Gas Inventory Compilation Guide is used, and the fuel emission factors are calculated with reference to the recommended values in the guide. The final selected emission factors are presented in *Table 1*. The methods recommended in the Provincial Inventory Guide are also applied to calculate the carbon emissions of the other three sectors, and relevant emission factors are selected to meet the recommended values for the study region in the guide.

Table 1. *Emission factors of carbon emission accounting process of energy activity sector*

Energy type	Average low calorific value (kJ/kg)	Carbon content value (tC/TJ)	Carbon oxidation rate	Emission factor ($kgCO_2/kg$)
Run-of-coal	20934	26.37	0.94	1.903
Cleaned coal	26344	25.41	0.96	2.356
Other coal washing	8363	25.41	0.96	0.748
Coke	28446	29.42	0.93	2.854
Coke oven gas	17385	13.58	0.99	0.857
Natural gas	38931	15.3	0.99	2.162
Liquefied petroleum gas	50242	17.2	0.98	3.105
Gasoline	44800	18.9	0.98	3.042
Diesel oil	43325	20.2	0.98	3.145
Kerosene	44750	19.6	0.98	3.152
Other petroleum products	45010	20.0	0.98	3.235

Analysis method of influencing factors

In conjunction with previous research conducted both domestically and internationally (Yang et al., 2011; Shen et al., 2018; Zhao et al., 2021; Zhang et al., 2021, 2022; Liu et al., 2022), as well as Handan City's current state of growth, the LMDI model is utilized to identify the variables that impact carbon emissions, the carbon emission decomposition model established by this study is as follows:

$$C = \sum_{ij} \frac{C_{ij}}{E_{ij}} \times \frac{E_{ij}}{E_i} \times \frac{E_i}{Q_i} \times \frac{Q_i}{Q} \times \frac{Q}{P} \times P = \sum_{ij} F_{ij} U_{ij} S_i I_{Si} AP \quad \text{(Eq.1)}$$

where, C is the total carbon emission. i and j represent different industries and different types of energy. E is energy consumption. Q is the gross regional product. A is GDP per capita.

The carbon emission change ΔC from "0" (base year) to "T" (target year) can be broken down into the following effects using the constructed LMDI decomposition model: the carbon emission coefficient effect (ΔC_F), the energy structure effect (ΔC_U), the energy intensity effect (ΔC_S), the industrial structure effect (ΔC_I), the economic growth effect (ΔC_A), and the population growth effect (ΔC_P). The decomposition equations for carbon emission change is as follows:

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$$\Delta C = C^T - C^0 = \Delta C_F + \Delta C_U + \Delta C_{Si} + \Delta C_{Is} + \Delta C_A + \Delta C_P \quad \text{(Eq.2)}$$

$$\Delta C_P = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} ln\left(\frac{P_{ij}^T}{P_{ij}^0}\right) \quad \text{(Eq.3)}$$

$$\Delta C_A = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} ln\left(\frac{A_{ij}^T}{A_{ij}^0}\right) \quad \text{(Eq.4)}$$

$$\Delta C_I = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} ln\left(\frac{Is_{ij}^T}{Is_{ij}^0}\right) \quad \text{(Eq.5)}$$

$$\Delta C_U = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} ln\left(\frac{U_{ij}^T}{U_{ij}^0}\right) \quad \text{(Eq.6)}$$

$$\Delta C_S = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} ln\left(\frac{S_{ij}^T}{S_{ij}^0}\right) \quad \text{(Eq.7)}$$

$$\Delta C_F = \sum_i \frac{C_i^T - C_i^0}{lnC_i^T - lnC_i^0} ln\left(\frac{F_{ij}^T}{F_{ij}^0}\right) \quad \text{(Eq.8)}$$

Since the carbon emission coefficient in the carbon emission accounting method adopted in this study is a fixed value of 44/12 (Dong et al., 2014), the contribution value ΔC_F of the carbon emission coefficient effect change in the equation is always 0, and subsequent analysis is not carried out.

Data sources

This research covers the years 2010 through 2022. The data on energy consumption, gross regional product, gross domestic product of the three types of industries, permanent population, industrial production, and agricultural activities are sourced from the Handan Statistical Yearbook. The "China City Statistical Yearbook" and the Handan Municipal Ecological Environment Bureau's official website provide the data needed for the waste treatment department. The classification of the industrial structure follows the current standard "Classification of National Economy Industries " (GB/T 4754 - 2017)" in China. This group includes forestry, fishing, agriculture, and animal husbandry as basic businesses. Secondary industries include mining, manufacturing, electricity, heat, gas, and water production and supply, as well as construction. The tertiary industry, known as the service industry, encompasses all other sectors aside from the primary and secondary industries.

Results and analysis

Accounting results

Carbon emission accounting results and change characteristics

Using the selected accounting method, the carbon emissions and total amount of four types of energy consumption Handan City from 2010 to 2022 were calculated, and the results are presented in *Figure 1*. Since fluctuation is a common phenomenon by

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analyzing time series, the temporal changes in carbon emissions in Handan City during the study period can be roughly divided into three stages: rising (2010-2014), continuous decline (2015-2017), and surge and stabilization (2018-2022). Regional carbon emissions grew at an average annual growth rate of around 5.38% throughout the rising stage, from 128.2240 million tons in 2010 to 158.1549 million tons in 2014. From 2015 to 2017, the carbon emissions in Handan City entered a stage of continuous decline, decreasing year by year. The average annual reduction was 6,402,400 tons, and the total carbon emissions decreased to 138,947,700 tons by the end of 2017. From 2018 to 2022, the carbon emissions in Handan City increased significantly compared to 2017. The carbon emissions in these five years were relatively high, and the inter - annual change was low, maintaining a fluctuation of around 159,000,000 tons.

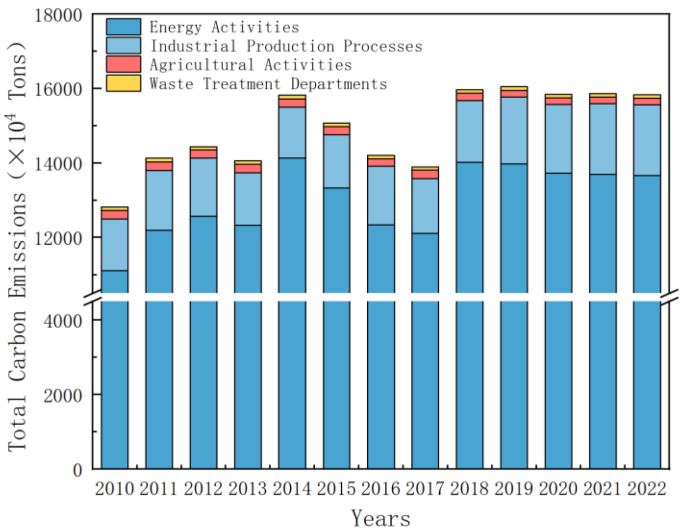

Figure 1. *Total carbon emissions and composition of Handan City from 2010 to 2022*

According to a review of the sources of carbon emissions, the main reason for the change in carbon emissions in Handan City is the shift in energy consumption in the energy activity sector. The average carbon emissions from the energy activity sector were 129,583,800 tons, mainly resulting from changes in fossil fuel consumption in the energy processing and conversion sector (including utility electricity and heat, oil and gas extraction and processing, solid fuels, and other energy production) and the steel sector, it was responsible for about 85% of the overall emissions. Although Handan City also implemented relevant epidemic prevention measures such as city lockdown during the COVID-19 pandemic period (2019-2021), the accounting results show that industrial emissions, as the main source of emissions, have not decreased due to the impact of relevant epidemic prevention policies. Results of other researchers' studies on various air contaminants are comparable to this accounting conclusion (Niu et al., 2022). Overall, the industrial production process sector's carbon emissions were lower than those of the energy activity sector, with an average of 15,827,900 tons. The proportion of total emissions in the city was basically maintained at around 10%. The carbon emissions of the agricultural activities and waste treatment departments accounted for less than 3% of the total emissions in the city. Regional carbon emissions are driven by changes in energy activity, reflecting Handan City's dependence on traditional fossil energy as a resource-based city.

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Decomposition results of carbon emission in Handan City

Based on the established LMDI model, 2010 was selected as the base year, and the cumulative carbon emission changes in Handan City from 2010 to 2022 are decomposed according to the equations in the above chapter (*Eq.1* to *Eq.8*). Results are shown in *Table 2* and *Figure 2*.

Table 2. *Decomposition results of the effects of influencing factors on carbon emission in Handan City from 2010 to 2022*

Year	Energy structure effect (ΔC_U)	Energy intensity effect (ΔC_{Si})	Industrial structure effect (ΔC_{Is})	Population effect (ΔC_P)	Economic effect (ΔC_A)	Total effect
2010-2011	189.33	-1054.20	121.97	208.63	1841.72	1307.45
2011-2012	-116.12	-352.37	-262.99	170.12	879.76	318.39
2012-2013	-97.99	105.55	-516.57	229.19	-112.86	-392.68
2013-2014	784.56	1005.46	-350.23	274.02	46.11	1759.93
2014-2015	-71.07	-96.64	-749.45	227.16	-53.79	-743.79
2015-2016	-614.79	-1115.72	195.60	13.82	658.53	-862.56
2016-2017	-87.15	-342.59	86.87	-47.91	76.41	-314.37
2017-2018	1799.91	943.33	-551.05	164.90	-286.42	2070.67
2018-2019	-742.62	442.97	-505.20	43.27	839.95	78.37
2019-2020	306.81	-899.07	-183.07	-13.79	487.56	-348.62
2020-2021	151.97	-191.18	-193.55	4.18	251.14	22.57
2021-2022	61.83	-249.60	-84.32	4.23	237.30	-30.56
Total	1564.67	-1804.06	-2991.99	1277.82	4865.41	2911.86

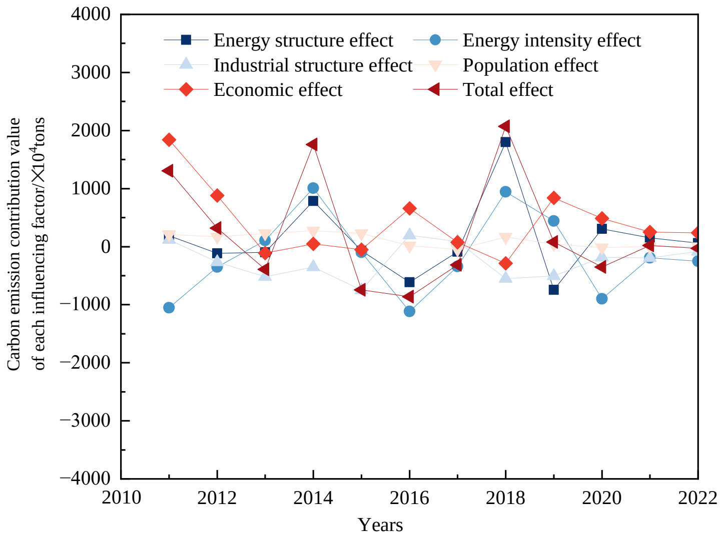

Figure 2. *Cumulative decomposition results of factors affecting carbon emissions in Handan City from 2010 to 2022*

According to *Figure 2*, the total effect of five influencing factors on the carbon emission of Handan City from 2011 to 2022 are all promoting effects compared with 2010, with an average annual increase of 3.5793 million tons. Among them, the region's average yearly carbon emissions have increased by 1.2579 million tons due to population growth and 6.0367 million tons due to economic further growth. The primary cause of

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Handan City's rising carbon emissions is the expansion of the area economy. Apart from the role played by the industrial structure impact, regional carbon emissions increased in 2011, the other years are the inhibition effect, which reduces regional carbon emissions by -15.8399 million tons per year, accounting for -72.80% of the total effect. The overall shift in regional carbon emissions was aided by the energy structure impact, with an average contribution rate of 30.79%, while the energy intensity effect inhibited it, with an average contribution rate of -53.38%. However, the contribution values of the two groups varied greatly in each year, reflecting the great changes in regional energy demand and consumption in each year of the study period.

Analysis of the impact of various factors

Population factors

The change of the influence of the population effect is similar to the changing trend of the regional population size. As shown in *Figure 3*, the permanent population of Handan decreases slightly in 2017, 2020, and 2022 compared with the previous year, but increases year by year in other years. In 2019, the permanent population of Handan is 9.4166 million, reaching the maximum value in the study period. The population effect's carbon emissions this year were 12.832 million tons, with an average contribution rate of 43.50%. From 2020 to 2022, the permanent population of Handan City begins to decrease to 9.3669 million at the end of 2022, and the carbon emission of the regional population effect is reduced to 12.5791 million tons. The trend of population change in the region relates to the impact of demographic variables on carbon emissions in Handan City. The change trend of per capita carbon emissions was still varying over the research period, despite the low population size change range. This suggests that population expansion had a negligible impact on the change in total carbon emissions. Therefore, in the face of carbon emissions caused by population factors, priority should be given to strategies to reduce per capita carbon emissions, such as encouraging residents to use electrified equipment for cooking and heating, encouraging cycling and walking or using new energy vehicles, strengthening green knowledge education, and advocating a low-carbon lifestyle, in order to lower the region's per capita carbon emissions.

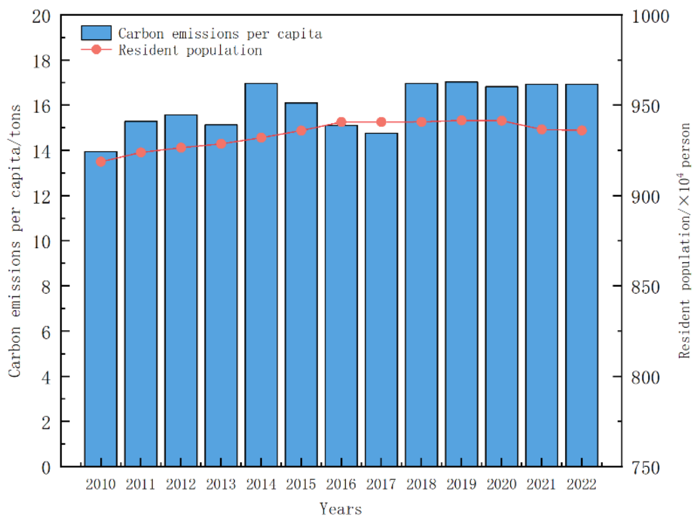

Figure 3. *Handan City's permanent population and per capita carbon emissions from 2010 to 2022*

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Economic factors

The primary cause of Handan City's carbon emissions is the economic impact. Based on statistical data outcomes, as displayed in *Figure 4*, Handan City has a rapid economic development from 2010 to 2022, with the gross regional product increasing from 236.156 billion yuan to 411.480 billion yuan, and the average annual carbon emission contributed by the economic effect is 2.8463 million tons, accounting for 151.98% of the total effect. According to the breakdown of influencing factors year by year in *Table 2*, the carbon emissions caused by economic growth in Handan City decreased in 2013, 2015, and 2018 compared with the previous year, but increased in other years. In 2011, the growth reached 18.4172 million tons compared with the previous year, and the contribution rate reached 140.86%. With the national "steady growth" of the overall economic work of the domestic background unchanged, Handan City's "14th Five-Year Plan" goals also clearly pointed out to continue to expand the domestic market. Handan City's future GDP growth momentum is strong, and the carbon emissions brought by the economic effect may further increase. Therefore, industrial enterprises should be encouraged to implement low-carbon technology, negative-carbon technology, speed up the steel and chemical industry in Handan City into the zone into the park, the implementation of key transformation demonstration projects, to create a "zero-carbon park" sample demonstration, while encouraging enterprises to actively integrate into the carbon market trading, in order to broaden corporate financing channels.

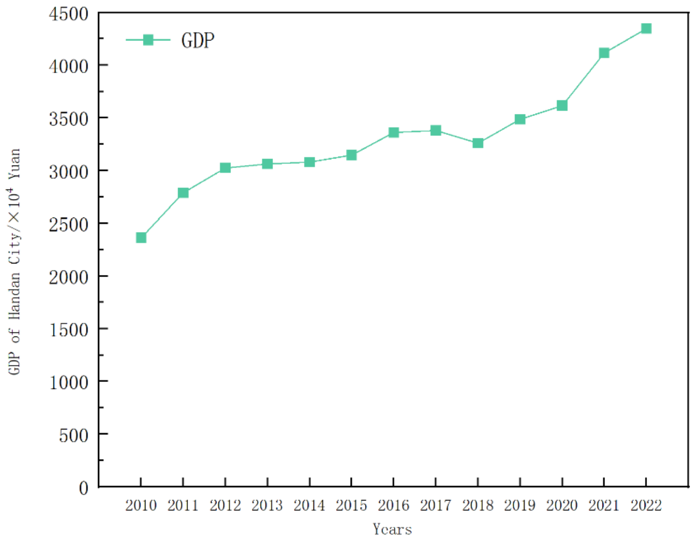

Figure 4. *Regional GDP of Handan City from 2010 to 2022*

Industrial structure factors

The primary factor limiting carbon emissions in Handan City is the industrial structure, which also has a significant annual impact on the decrease of carbon emissions throughout the region. One of the topics of the Handan Municipal Government Work Report during the study period is the modification of the industrial structure. By the end of the "13th Five-Year Plan," Handan City's industrial structure has been adjusted and optimized to complete the transition from "twenty-one" to "thirty-one," and the industrial proportion effect's carbon emissions have decreased from 1.2197 million tons to -36.7463 million

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tons, or -72.80% of the total effect annually. With the encouragement of regional policies for the development of the tertiary industry and the transformation of the industrial structure, as demonstrated by the further breakdown of the carbon emissions of three industries in Handan (*Fig. 5*), the tertiary industry's contribution to the carbon emissions from the effect of industrial structure shows a positive increase year by year. Compared with 2010, the carbon emission contribution value of the tertiary industry in Handan City was -0.22 million tons in 2011, rising to 0.5177 million tons by 2022. With an average contribution rate of -69.48%, the secondary industry's contribution dropped from 1.2348 million tons in 2011 to -0.2844 million tons in 2022. The decrease in the percentage of secondary industry is the primary cause of Handan City's industrial structure's inhibitory influence on regional carbon emissions. It is evident from the decomposition findings that lowering the secondary industry's scale contributes to a decrease in regional carbon emissions. Although Handan City has made some progress in transforming its industrial structure, more may be done to lower the secondary industry's carbon emissions in the future. Therefore, it is necessary to upgrade the technology and product extension of the secondary industry, while developing the tertiary industry on the basis of the original industry, and accelerating the construction of new materials, new energy, and biohealth strategic emerging industry systems.

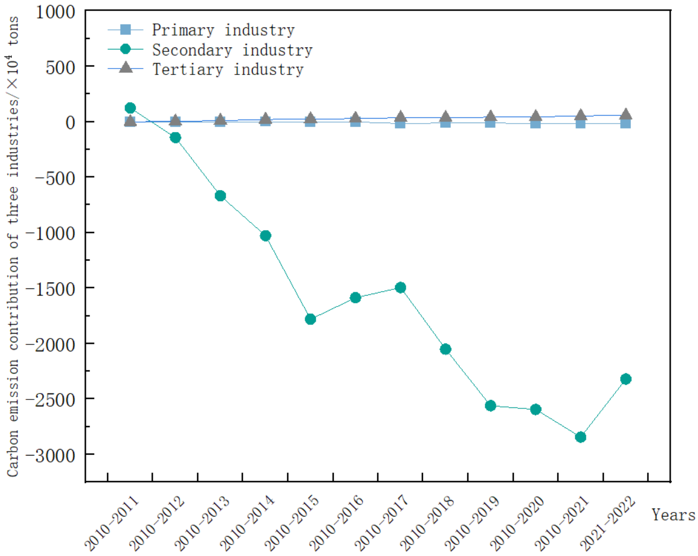

Figure 5. *Carbon emission contribution of the three industries in Handan City from 2010 to 2022*

Energy intensity factors

One efficient strategy to lower Handan City's overall carbon emissions is to lower the energy intensity of the secondary industries. The energy intensity effect also inhibited regional carbon emissions. With an average contribution rate of -90.88%, -140.65%, and -63.07%, respectively, energy intensity in 2010–2013, 2016–2018, and 2020–2022 has a significant inhibitory influence on carbon emissions in Handan City, as shown in *Figure 2*. According to the changes of energy intensity in Handan City from 2010 to 2022 (*Fig. 6*), the energy intensity of Handan City rebounds and increases after 2014 and 2018, respectively. However, the energy intensity is less than 1.36 tons of standard

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coal/10,000 yuan in 2010, and the corresponding inhibitory contribution value of the energy intensity effect is reduced. It is necessary to integrate the analysis of industrial economy and energy consumption with the energy intensity impact. By using standard coal, the main industry's energy consumption in Handan increased from 0.30% in 2010 to 0.34% in 2019. Over the last 10 years, the secondary industry's share of energy consumption has dropped from 98.98% to 98.43%. The tertiary sector's energy consumption grew from 0.72% to 1.23%, and the impact of the shift in industrial percentage on energy intensity also changed at the same time. It is evident that the secondary industry's drop in energy intensity is primarily responsible for the inhibitory effect of the carbon reduction effect of energy intensity. In the future urban development planning of Handan City, efforts can be made in the promotion of low-carbon energy-saving technology, utilization of energy-saving materials, energy-saving building design, energy-saving management, and other aspects of the secondary industry. Handan City can deeply carry out enterprise energy-saving diagnosis, tap the energy-saving potential of key enterprises such as steel and chemical industries. Urban carbon emissions can be decreased by increasing energy efficiency and enticing businesses to implement carbon capture technologies.

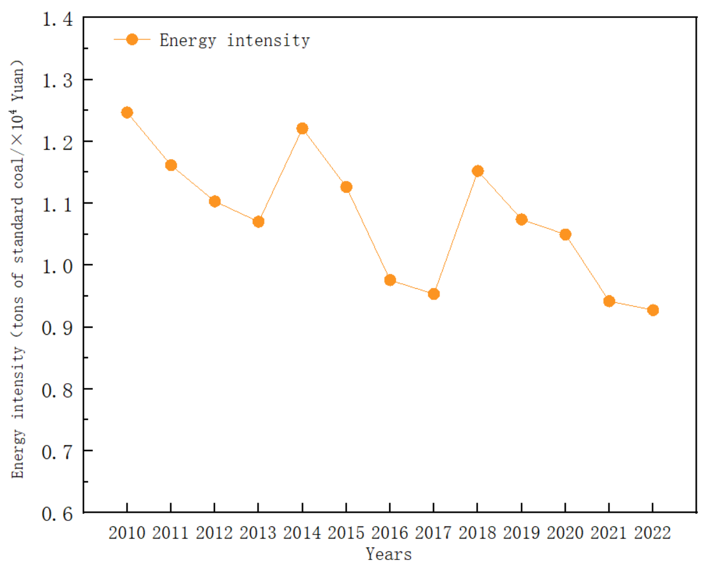

Figure 6. *Energy intensity of Handan City from 2010 to 2022*

Energy structure factors

Reducing the use of coal energy is the key to adjusting the energy structure. Due to rich mineral resources, the energy structure of Handan City is dominated by coal, with oil and gas as auxiliary energy. In 2010, the consumption of raw coal, washed fine coal and other washed coal in Handan City was 51,324,036 tons, 20,292,328 tons and 972,634 tons respectively. By 2014, the consumption of these three types of coal reached 57,133,958 tons, 22,874,616 tons and 441,418 tons respectively. In 2018, the consumption of the three types of coal reached 50,165,090 tons, 26,038,513 tons and 3,699,802 tons. In 2014-2015 and 2018-2022, the consumption of coal in Handan City has increased compared with that in 2010. The energy structure effect's contribution to Handan City's development in carbon emissions is likewise mostly focused in 2014–2015

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and 2018–2022, as shown in *Figure 2*. Among them, the average contribution value in 2014-2015 was 7.2424 million tons, and the average contribution rate was 27.63%, respectively. From 2018 to 2022, the contribution value is 14.0558 million tons, with an average contribution rate of 46.60%. The carbon emissions from coal energy have a stronger correlation with Handan City's overall carbon emissions. From 2018 to 2022, the consumption of raw coal, clean coal and other washed coal in Handan City basically maintained a small increase of less than 3%. However, Handan City's carbon emissions remained in the state of carbon balance due to changes in coal consumption and the optimization of the city's industrial structure. Therefore, in the future, in addition to reducing the consumption of traditional coal energy, Handan's energy structure transformation should also actively expand the use of clean energy and increase the proportion of non-fossil energy in energy consumption. Carry out promotion or policy incentives in key industries such as energy cleanliness, waste heat utilization, green electricity, and green hydrogen.

Discussion

At present, resource-based cities are still facing difficulties in transformation, such as weak endogenous driving force for transformation and insufficient innovation capabilities. We selected Handan as a typical sample of resource-declining cities for analysis. It will be more advantageous to optimize the industrial structure, enhance energy efficiency and sustainable development, and act as an intermediary between technological innovation capabilities and resource allocation efficiency in order to support the economic transformation and development of resource-declining cities. As the economic magnitude of various cities continues to grow, greenhouse gas emissions will also increase. Green technology, innovation capabilities, energy use, and other avenues should be the main focus of resource-based city transformation. Industrial succession and replacement should be gradually realized, and variations in urban life cycles and development levels should be taken into consideration. The long-term mechanism for resource-based city transformation should also be continuously improved.

While the study has produced some results, there are still certain shortcomings because of certain objective factors. The GWP (global warming potential) of various greenhouse gases in each year is dynamically changing, but due to the long research period, in the process of energy carbon emissions accounting in this project research process, the reference source of this value is not unified, but the change is small. Therefore, this study uses the fixed value recommended by the Sixth Assessment Report (AR6) produced by IPCC (The Intergovernmental Panel on Climate Change) for calculation, which may lead to a certain error in the final result. Other scholars can optimize this feature.

Conclusions

This paper mainly calculates the total carbon emissions of four sectors in Handan City, briefly analyzed the carbon emissions of Handan City. And used the LMDI model to investigate the factors that are driving the rise in carbon emissions in Handan City. Based on the accounting results, and finally draws the following conclusions:

(1) Between 2010 and 2022, Handan's overall carbon emissions had a varying rising trend, with the energy activity sector accounting for the majority of the city's carbon emissions. The city's overall carbon emissions over the research period were consistently

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more than 85%, and the order of emissions was energy activities > industrial production process > agricultural production > waste treatment.

(2) The cumulative total effect of the five influencing factors from 2011 to 2022 is always positive, and the combined effect of various influencing factors will increase carbon emissions by 28.2885 million tons compared with 2010. With 12.5792 million tons of carbon emissions from 2011 to 2022, Handan City's population effect on carbon emissions is comparable to the area population's changing trend. The region's overall carbon emissions have consistently increased due to the economic impact, which is also the primary cause of carbon emissions, accounting for 60.3669 million tons of emissions between 2011 and 2022.

(3) The decline of the secondary industry's share is the primary cause of Handan City's industrial structure's inhibitory influence on regional carbon emissions between 2011 and 2022. Reduced carbon emissions due to industrial restructuring are -36.7463 million tons. Regional carbon emissions were also suppressed by the energy intensity impact, and the total carbon emissions from 2011 to 2022 were -22.329 million tons.

(4) In order to serve as a guide for the low-carbon development of Handan City and other resource-based cities, recommendations are made in accordance with the study of the many elements that contribute to carbon emissions in the city.

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