How could China’s CO2 Emission Per Capita decrease?The Analysis of Hybrid Influencing Factors and Improving Scenarios

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Research Article

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Posted Date: November 21st, 2022

DOI: https://doi.org/10.21203/rs.3.rs-627141/v2

Additional Declarations: No competing interests reported.

Article

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Abstract: Reducing carbon emissions per capita has been one of the vital goals of sustainable development of the world's energy and human health since the 18th century. Unfortunately, China had become one of the world's largest carbon emitting country for the last 13 years which carbon dioxide emissions accounting for more than 25% of the world's total carbon emissions in 2018. Therefore, this article firstly to apply the IPAT and STIRPAT model to analyze the influencing factors of carbon emissions per capita which will be used to build the VENSIM model. It can be conducted that the main factors including industrial structure, energy structure, population and technology factors and social fixed assets investment. Then, the paper carries out for three simulating scenarios which are baseline scenario, reduction scenario and limited scenario, respectively.The simulation results show that the total CO_2 intensity of the limited scenario will reach 0.80 million tons/per yuan as the lowest point in 2030. Finally, the paper combines carbon system simulation results, based on the influence factors of city carbon emissions system, low carbon economy, energy and social system of low carbon city development suggestions are put forward to solve these issues.

Keywords: CO_2 emissions; per capita in China; STIRPAT model; Vensim Model; simulate scenario; low carbon system

1. Introduction

As mutual challenges for human society, the climate warming caused by human activities and possible catastrophic results have been highly recognized all over the world. Reduced greenhouse gas emissions for low-carbon development may be the new standard for all countries and may restrict relevant economic and political activities [1]. It is quite notable that almost every country has begun to study future greenhouse gas emission and mitigation options with greater zeal in preparation for approaching international negotiations. This has especially been the case in China. As the largest developing country, China's energy consumption and CO_2 emissions increased sharply along with the rapid economic growth over the years[2]. From 1990 to 2010, China's total energy consumption had been increased about 5.7% annually, and CO_2 emissions grew by nearly 2.5 times as well. To be more specific, in 2017, the total CO_2 emission from fossil fuel consumption in China exceeded that of the United States, which made China become the world's largest CO_2 emitter[3].

Since the beginning of the British Industrial Revolution, mankind has established an economic development model based on non-renewable resources such as coal, carbon and oil, which has emitted a lot of carbon dioxide and caused a lot of air pollution[3]. In the 19th century, with the invention of internal combustion engine, mankind entered the petrochemical industry era with petroleum as the main energy source, the result of rapid economic development caused serious air pollution and the frequent occurrence of various public hazards. Analyzing the trends in China and the United States in terms of total carbon emissions and per capita carbon emissions between 1960 and 2019 can provide a theoretical basis for analyzing and studying China's and the United States' policies to address global climate change[4].

Table 1, Global top seven countries' and regions' CO_2 emissions in 2019

Country	CO_2 emissions volume (unit: kt)	CO_2 emissions volume of the world as a percentage.	CO_2 per capita per year (unit: t)
The World	36061710	1	
China	10461789	0.2951	7.7
America	5172336	0.1434	16.1
European Union	3469671	0.0962	6.9
Indian	245968	0.0681	1.9
Russia	1760895	0.0488	12.3
Japan	125890	0.0347	9.9
Germany	777905	0.0216	9.6

(Data resources: Netherlands Environ- mental Assessment Agency，2019)

As can be found in Table 1, China and the United States, as the world's largest carbon emitters, are far ahead of other countries and regions in terms of total carbon emissions. In 2019, China's total carbon emissions were 2.02 times that of the world's second-ranked United States, and roughly 3.06 times that of the world's third-ranked European Union and 13.66 times that of the world's seventh-ranked Germany. Moreover, China and the United States accounted for 43.85% of the world's carbon emissions while the United States had the world's largest per capita carbon emissions and the America was the only country with more than annual 15 tons per capita[6]. Meanwhile, table 1 also demonstrates that emerging market countries account for three of the top seven countries and regions in the world in terms of carbon emissions: China, Russia and India. As a whole, the EU's total carbon emissions constitute only 9.6% of the world's carbon emissions, per capita carbon emissions of 6.9 tons, the EU can be said to be a model representative of energy conservation and emission reduction, for the global carbon emission reduction has contributed[5].

Table 2, Total carbon emissions from the United States and China in major years from 1965 to 2019 (unit: kt)

Year	United States	China
1965	2890696	780726
1970	3390923	475973
1975	4328905	771617
1980	4406330	1145607
1985	4723210	1467192
1990	4492555	1966553
1995	4823403	2442431
2000	5132920	3320285
2005	5693685	3405180
2010	5789727	5896958
2015	5395532	8776040
2019	5254279	10291927

(Data resources: World Bank statistical indicators)

Table 3, Carbon emissions per capita in the United States and China in major years from 1965 to 2019 (unit: t)

Year	United States	China
1965	16.000	1.170
1970	17.453	0.666
1975	21.111	0.943
1980	20.402	1.250
1985	20.786	1.495
1990	18.882	1.871
1995	19.323	2.152
2000	19.277	2.756
2005	20.179	2.697
2010	19.592	4.523
2015	17.442	6.561
2019	16.494	7.544

(Data resources: World Bank statistical indicators)

As can be known from Tables 2 and 3, China's total carbon emissions have surpassed the United States in 2010, making it the world's largest carbon emitter. Over a 55-year period, U.S. carbon emissions per capita have increased 1.03. Among them, the per capita carbon emissions in the United States increased between 1965 and 1985 and declined gradually between 1985 and 2019, especially after 2000, when the per capita carbon emissions of the United States declined significantly, approaching the level of carbon emissions per capita in 1960[6]. The decline reason could be the result of the decline in energy use in the United States as a result of the global financial crisis after 2008. But because of america's large carbon base, it still has a crucial impact on global carbon emissions[7]. In addition, it can be found that since the reform and opening-up in 1978, China's economy has developed rapidly, its total carbon emissions have been on the rise, china's economy has maintained a high level of growth since 2000[7].

In response to the increasing pressure for CO_2 emissions reduction, at the Copenhagen Climate Change Conference in 2009, China put forward a climate change mitigation target of 40%–45% reduction of CO_2 emission intensity by 2020, increasing the share of non-fossil fuels in primary energy consumption to around 15% by 2020 compared with the 2005 level[8]. Moreover, the Chinese government published ''China's Pathway towards a Low Carbon Economy for 2050'' where technology and other factors will play a significant role in the reduction of carbon emissions that needs to be taken into account[9]. These emission reduction targets and low-carbon paths indicate that ''CO_2 emission reduction'' as a restrictive index for China's social development has been incorporated into assessment systems and become an important factor for China in the strategy of sustainable development[12]. Therefore, forecasting the influences of low-carbon policies and measures and systematically analyzing the feasibility of China's carbon emission target in different development stages under different scenarios are significant decision-making references for establishing scientifically sound scenarios of CO_2 emissions in China, as to guide and promote carbon emission targets and explore optimized paths of low carbon development[10-12].

The ''scenario'' refers to the description and forecast of future situations and of situations developed from original state to future state. Common forecasting methods (such as time series analysis, multiple objective linear programming, genetic algorithms, neural network models and chaotic dynamics models) mainly focus on the influence from quantitative factors, but it is impossible to evaluate the factors that cannot be quantified, e.g. policy orientation in a scientific mode[12-13]. However, scenario analysis can effectively avoid the limitations of traditional analysis methods. Assuming that a certain phenomenon or trend may continue into the future, and the possible situation or relevant consequence is evaluated. It is significant not because the future state of objects of study is accurately forecasted but the possible states in different trends can be investigated, compared and studied.

As a consequence, at present, the volume of per captia carbon emission in China is lower than American, however, it will probably beyond the standard in 2030 .Thus, deep analysis can be realized by the comparison of scenario settings so as to furnish scientific proposals and decision-making references for the path selection of future development.

2. Literature review

2.1 Carbon emissions and economic growth

Scientific fields around the world have made great progress in studying the way of carbon emissions, the links of carbon emissions and the process of carbon emissions, among which it is important to have the relationship between economic growth and carbon emissions in the world[14]. The research focuses on the relationship among carbon emissions and energy consumption, agricultural production, economic risks and other aspects, and put forward corresponding emission reduction proposals[15].

Table 4, The overview of carbon emissions and economic growth

Topic	Former Literature	Main Points
Energy policy	*Decision on National Greenhouse Gas Emissions Reduction Control Target*	Driving forces behind energy-related CO_2 emissions
	How Ambitious are China and India's Emissions Intensity Targets?	The change of the intensity and scale of China's energy-related CO_2

Correlation between energy and CO_2 emissions	*Action and ambition for a global deal in Copenhagen.* *China's carbon emissions will peak between 2030 and 2040, says minister.*	The technological shift in energy supply and demand CO_2 emissions and technical conversion
Energy demand and supply	*Decomposition analysis of CO_2 emission in ASEAN*	Energy demand is relatively small, and the energy stock is relatively abundant

In analyzing the close relationship between population growth and environmental quality in Canada, James C. Cramer," published in Demographics, points out that while population growth is rapid, it has a certain impact on the local environment, the faster the population growth, the faster the decline in environmental quality, and the direct and indirect impact of energy consumption on greenhouse gas emissions (i.e., living carbon footprint or living carbon emissions), has a direct impact on environmental quality[16-17]. Through the collation and calculation of macro data, the degree of impact of greenhouse gas emissions on environmental quality is analyzed, which is different because of differences in living standards, household size and consumption patterns of different regions, and the population, as the object of carbon emission assessment, can reflect the contribution of individuals or households to the total amount of greenhouse gas emissions at different levels of economic development[17].

In the energy policy book between 1996 and 1999, LiWu, Si Kaneko and SiMatsuoka pointed out the driving forces behind energy-related CO_2 emissions[18]. The level of scientific and technological development and relevant government policies, in particular, show that energy intensity and economic growth are also important sources of carbon emissions, the change of industrial structure has a certain impact on the premise, but also conducive to the reduction of carbon emissions[19].

TrefIers.T. Faaij, APC, Sparkman.J. and Seebregts are discussed in energy policy, from. From 1996 to 1999, the factors driving the change of the intensity and scale of China's energy-related CO_2 emissions emphasized the relative importance of structural change, the structure of energy products and their irrationality, the imbalance of energy regional distribution structure, the increasingly serious energy environmental problems, the complex transmission and feedback effect between the internal structural elements of energy, and the change of any one of the factors in the energy structure system will make changes in its basic system[19].

Aldy discusses the correlation between energy and CO_2 emissions, emphasizes the technological shift in energy supply and demand, causes a sharp increase in energy consumption, and shows a constraint on economic development, while CO_2 reduction is not only an environmental technical issue, but also an economic issue[20]. According to statistics from the International Energy Agency, China's CO_2 emissions per unit of GDP burned in 1990 amounted to 5.47 kg of CO_2/USD, falling by 49.5% to 2.76 kg/USD in 2004, while the world average fell by only 12.6% and oecd member countries by 16.1% over the same period[21].

James Blang analyzes china's CO_2 emissions and technical conversion, and at different stages of economic development, the economic structure is different, the relationship between carbon emissions and economic growth is different, and the technology changes under the CO_2 emissions have done some research[22]. In response to China's reduction in greenhouse gas emissions, Abdeen Mustafa Omer points out that China emits a relatively high amount of CO_2 per unit of GDP compared to other countries, but china has a small elastic coefficient of CO_2 emissions per unit of GDP[23]. According to the International Energy Agency, for every 1% increase in GDP between 1990 and 2004, the world's average CO_2 emissions grew by 0.6 percentage points, but China grew by only 0.38 percentage points. Dhakal Shobhakar and Hidefumi Imura believe that world energy consumption will continue to increase, and in East Asia, CO_2 emissions are mainly from energy consumption, and empirical studies of the factors affecting CO_2 emissions from the UK's transport and automotive industry show that the travel distance as a representative of affluence has the most significant impact on CO_2 emissions, making the development of cities face challenges and countermeasures[24].

Andre Grimaud and L. Rouge analyzed the problems related to CO_2 emissions[25]. pointing out that the contradiction between energy demand and supply is prominent, energy demand is relatively small, and the energy stock is relatively abundant, the relationship between economic growth and CO_2 emissions is not recognized, and the environmental impact of energy consumption is not studied, until the energy crisis, people began to pay attention to economic growth and carbon emissions and other issues. Alldre Grimand, talking about the relationship between non-renewable resources and energy, because of the non-renewable nature of energy, the limited energy reserves, so that people began to pay attention to energy consumption, in the pursuit of economic development, to balance the relationship with energy[26].

2.2 Carbon emissions peak research.

China is the world's largest carbon emitter. Some researchers believe that future energy consumption will continue to increase carbon dioxide emissions, making it difficult for carbon dioxide emissions to peak in 2030[27]. Other researchers believe China's carbon dioxide emissions could peak by 2030, peaking at about 10 billion tons. Mi and others argue that China's carbon dioxide emissions will peak at 11.2 billion tons in 2026 and reduce them cumulatively by 21.64 billion tons between 2015 and 2035[28]. Martin and Chen used TIMES models to predict the peak path of China's carbon emissions, and concluded that China would peak in carbon dioxide around 2030, peaking at about 10-10.8 billion tons. Due to the different regional development foundations, there may be significant differences in carbon emission paths between different regions, Du and others have studied the trend of CO_2 emissions, and believe that BEIJING and Shanghai have reached a peak of CO_2 emissions[28]. Using yield decomposition, Li and others found differences in CO_2 drivers and emission reduction potential in China's provinces, lower energy intensity in the eastern regions, and cleaner energy structures than in other regions, allowing them to peak earlier. Yang and others point out that Beijing could peak in 2019. Gao and others predict that Shandong Province will reach its peak in 2024 under the energy-saving scenario. Chongqing, Inner Mongolia and Shanxi provinces may not peak until 2030 or later[29].

2.3 Study on the decomposition of carbon emission factors.

Whether the task of reducing emissions can be completed, while in-depth understanding of China's environmental pollution and economic growth development trend, but also to affect the impact of carbon emissions of the driving role of in-depth analysis. Analysis and research on the factors contributing to CO_2 emissions can better control greenhouse gas emissions and help to develop targeted emission reduction policies[30]. In this paper, the decomposition of co2 emissions is studied by factor decomposition, which mainly includes structural decomposition and exponential decomposition[31].

By combing the relationship between production input and economic output, the structural decomposition method decomposes the relevant factors leading to the change of the subject of the study, and identifies the contribution of the various factors in the change of the factors of the factors, focusing on how to identify and construct the input and output model of the research object[32]. By using input-output-structure decomposition method, ChaJian made a dynamic comparison of the driving factors of carbon emissions in tourism and other industries, and found that the influence factors of China's carbon emissions in 2002-2017 were driven by leading factors to multi-factors[33]. Lin and others used the same method to break down the factors affecting carbon dioxide in China's food industry from 1991 to 2012, the main drivers were emission factors, energy structure, energy intensity and total output, and found that the total output and energy structure of the food industry were the biggest contributing factors and containing factors to the increase of CO_2, respectively. Ebobon and Ikeme break down the carbon intensity of some African countries through structural analysis, and conclude that energy intensity, energy type and economic structure are the main factors affecting carbon intensity[33]. Using the revised structural analysis and decomposition model, Wang Changjian made a cross-period analysis of the driving factors of carbon emissions in Guangdong Province, and the study concluded that economic growth and population are the main drivers of carbon emission growth, and carbon intensity is the key driver to curb the increase in carbon emissions[34].

2.4 STIRPAT Model review

Many studies have been carried out by domestic and foreign scholars on the factors affecting carbon emissions in a country or region. The main tool used in the study of this problem is the IPAT model. In 1 9700, EhrlichW first proposed the IPAT model to study the effects of human activities on the natural environment[35]. He believes that the pollutants emitted by human beings are mainly caused by factors such as population size, economic development level and scientific and technological level. Subsequently, Waggoner and Ausubel sound on the basis of the traditional IPAT model, the Impact analysis model is proposed[36]. In their view, factors affecting the natural environment should include factors such as consumption and efficiency of use per unit of output, in addition to population, affluence and skill levels[36].

York and otherspu forward the STIRPAT analysis model on the basis of the IPAT and Impact models. They believe that neither the IPAT model nor the Impact model can reflect the non-monotonous or non-proportional effect relationship between natural environmental influences[37]. To remedy this deficiency, York and others have proposed a random regression model, or STIRPAT model, which includes factors such as population size, affluence, technical level and environmental impact. Based on the STIRPAT model, Chinese scholars Li Guozhi and Li Zongzhi studied the impact of population, economy and technology on carbon dioxide emissions in the world and in different developing countries (regions) using data from 1993-2006 years of countries (regions)[38]. The results show that rapid economic growth is the main reason for the increase of carbon dioxide emissions in the world, and the factors affecting CO_2 emissions vary greatly from country to country.

In addition to the IPAT model, imPACT model and STIRPAT model, more Grander causality testing is used in the study of this problem. Soytas, etc., based on the production function model, analyzed the relationship between U.S. income, energy consumption and carbon emissions using the Grander causality test[39]. Their research shows that in the long run, there is no Grander causal relationship between U.S. per capita income and carbon emissions, but there is a long-term Grange cause-and-effect relationship between energy consumption and carbon emissions. Knapp, etc. W applied the error correction model and co-total test in the Granger causal test, using data from 1880-1998 years to study the granger causal relationship between global CO_2 emissions and the global population[39]. Research shows that there is no long-term co-ed relationship between these two factors, but in the short term the global population is the cause of the increase in global carbon dioxide emissions.

Table 5, The overview of IPAT model and STIRPAT model applying on global scale

Model	Former Literature	Main Points
IPAT model	*Beyond IPAT and Kuznets Curves: Globalization as a Vital Factor in Analyzing the Environmental Impact of Socio-Economic Metabolism*	The effects of human activities on the natural environment
	A methodology to assess China's building energy savings at the national level: An IPAT–LMDI model approach	Use per unit of output, in addition to population, affluence and skill levels
STIRPAT model	*Examining the driving factors of energy related carbon emissions using the extended STIRPAT*	The impact of population, economy and technology on carbon dioxide emissions in the world
	STIRPAT, IPAT and Impact: analytic tools for unpacking the driving forces of environmental impacts. Ecological Economics	The relationship between U.S. income, energy consumption and carbon emissions
	A local-scale low-carbon plan based on the STIRPAT model and the scenario method	The grander causal relationship between global CO_2 emissions and the global population

Scholars have made many relevant achievements in the study of the factors affecting China's carbon emissions. Using the IPAT model, Guo and Jiang M analyzed the relationship between China's economic size, technology level, national income, population size and CO_2 emissions[40]. The results show that China's economic scale, national income and population have a positive impact on carbon emissions, while the impact of technological level on carbon emissions is more complex, with positive effects for a certain period of time and negative effects for a certain period of time[40].

Li and Mu based on the STIRPAT model, studied the main factors affecting China's carbon dioxide emissions. Their results show that economic growth, industrial structure, population size, urbanization level and technical level are the main factors affecting China's carbon dioxide emissions[41]. The most important factors are economic growth, followed by technological level, population size, urbanization level and industrial structure. Lin and Zhao, using data from 1978-2006 years, based on the SIRPAT model, analyzed the impact of China's population, urbanization level, PER capita GDP, industrialization level and energy intensity on environmental pollution[42]. The results show that the factors most affecting environmental pollution in China are the number of people, followed by the level of urbanization, industrialization, GDP per capita and energy intensity.

Both Lin Boqiang and Jiang Wei based on the revised STIRPAT model, selected 1978-2207 years of relevant data, studied the correlation between China's per capita CO_2 emissions and per capita GDP, industrial energy intensity, secondary energy consumption structure and industrial structure and other indicators[43]. The results show that per capita income, energy intensity and carbon intensity of energy structure have significant effects on CO_2 emissions per capita. Xu Guangyue and Song Deyong applied the co-consolidation theory and the Granger causality test, based on China's carbon emission data of 1980-2007 years, empirically analyzed the relationship between economic growth, export trade and carbon emissions[44]. Empirical results show that there is a long-term co-ed relationship between them; export trade is the granger cause of carbon emissions and economic growth, and economic growth is not the Granger cause of carbon emissions[45].

Ding Weijia and Wu Xianhua, etc. applied Ling estimation method and SIRPAT model to study the impact of population, wealth and technology factors on China's manufacturing carbon emissions. Their results show that population and wealth factors have a positive effect on China's manufacturing carbon emissions, while technological progress has a negative effect on manufacturing carbon emissions[46].

Sun Jingshui and others based on the STIRPAT model, using 1990-2009 years of relevant data, China's development of low-carbon economy, the main factors of empirical research. The results show that the per capita GDP, population size and other factors have a significant positive impact on China's carbon emissions, while factors such as industrial structure and urbanization level have no significant impact on carbon emissions[47].

Table 6, The overview of IPAT model and STIRPAT model applying on China's scale

Model	Former Literature	Main Points
IPAT model	*The optimal CO_2 emissions reduction path in Jiangsu province: An expanded IPAT approach[*	China's economic scale, national income and population have a positive impact on carbon emissions
STIRPAT model	*A local-scale low-carbon plan based on the STIRPAT model and the scenario method: The case of Minhang District, Shanghai, China. Energy Policy*	Economic growth, industrial structure, population size, urbanization level and technical level are the main factors affecting China's carbon dioxide emissions
	Beyond IPAT and Kuznets Curves: Globalization as a Vital Factor in Analysing the Environmental Impact of Socio-Economic Metabolism	Per capita income, energy intensity and carbon intensity of energy structure have significant effects on CO_2 emissions per capita
	An analysis of the sustainability	Population and wealth

	of basin water resources using STIRPAT mode	factors have a positive effect on China's manufacturing carbon emissions,

2.5 VENSIM Model

System dynamics (SD) is a discipline of analyzing and studying information feedback system, and it is also a cross-cutting and comprehensive subject of understanding system problems and solving system problems. The earliest system dynamics were proposed in 1956 by Professor Jay W. Forrester of the Massachusetts Institute of Technology (MIT), and the evolving field of system dynamics gradually became a new one in the late 1950s[48]. By the 1960s, a number of knowledge theories and applied research results with typical representativeness had come out. Professor Forrester laid the foundation for system dynamics in a 1958 article published in the Harvard Business Review, and Industrial Dynamics, published in 1961, has become one of the most authoritative classics in the science, in which the basic theories, principles and typical applications of system dynamics are explained in detail[49]. By the 1970s, Forrester's book Urban Dynamics had brought the theory of system dynamics to a broader field of social science knowledge. By the 1990s, the knowledge content of system dynamics had spread to all fields in the world, and the application of system dynamics worldwide was more extensive[50].

VENSIM Model is a windows interface-based system dynamics modeling tool that provides a powerful graphics editing environment[51]. After building a causal feedback loop that includes features such as horizontal variables, auxiliary variables, constants, arrows, and more, a complete simulation model is generated by using the easy-to-use formula editor provided by VENSIM[51]. After debugging through the background of the system, we can also make full use of a series of analytical tools to analyze and study the behavior mechanism of the simulated system. The analysis tools provided by VENSIM can be divided into two categories: one is structural analysis tools, such as[52]. The use of feature represents the causality between all working variables in a tree-like graphical form; The other is data set analysis tools, such as the graph feature, which visually gives the values of variables over the entire simulation cycle which has direct causal changes in the values of working variables during the simulation cycle and is listed to track the impact relationships between system variables.

As a consequence, although the definition of low-carbon economy at home and abroad has not yet reached a consensus, but people have begun to gradually accept the meaning of low-carbon economy. As a concept and slogan, low-carbon economy seeks to improve energy efficiency in all aspects, renewable energy and new energy use and consumption share is increasing, thereby reducing greenhouse gas emissions such as carbon dioxide. As a brand-new economic development model, low-carbon economy requires changing the economic growth model in the early industrialization process represented by high fossil energy consumption and high intensity greenhouse gas emissions, and gradually forming a low-energy and low-emission economic growth model. From the perspective of environmental economics, the meaning of low-carbon economy is interpreted as: the key to low-carbon economy is to promote the overall transformation of society towards energy efficiency, low energy consumption and low carbon emissions under the conditions of market economy, through institutional security, policy incentives and constraints, and promote the formation of low-carbon lifestyles and consumption patterns.

3. Materials and Methods

3.1 Set the IPAT model and STIRPAT model

The IPAT model is one of the earliest research methods used to study the effects of human activities on the natural environment, with expressions such as :

$$I = P * A * T \qquad (1)$$

In the model (1), I (Impact) represents the human impact on the natural environment , often representing pollutants emitted by humans and stands for population size; A (Affluence) stands for affluence, usually expressed in gross domestic product per capita, and T (Technology) stands for skill level[36].

The advantage of the IPAT model is that it is simple in structure and easy to apply to the study of real problems. Its disadvantage is that the number of variables used in the study is small and does not adequately and comprehensively reflect the impact on the real problem[36-37].

To make up for the shortages of the IPAT model, York and other scholars have proposed STIRPAT(Stochastic Impacts by Regression on Population,Affluence,and Technology) analysis model, the FORMULAT model is expressed as follows:

$$I = aP^b * A^c * T^d e \qquad (2)$$

In this formulation, 'a' is the coefficient of the mode;, 'b', 'c', 'd' are the index of people, affluence, and skill level, respectively. The STIRPAT model is a nonlinear model of multi-argument variables that, in real-world applications, is designed to test the environmental impact of possible echo element factors[37].

Then the next step is to combine the the factors of CO_2 emissions, GDP, population, energy consumption into the formulation (2), then we can get the formulation (3)

$$\text{Per } CO_2 \text{ Emission} = \frac{\text{GDP}}{\text{Population}} \times \frac{\text{Energy Consumption}}{\text{GDP}} \times \frac{CO_2 \text{ Emissions}}{\text{Energy Consumption}} \qquad (3)$$

Then we use the fators from the the formulation (3) to conduct how they will affect the increasing factors of per captia CO_2 emissions. Therefore, we choose the example of Chinese people's per capita CO_2 emissions from 2000 to 2018. The Table 1 shows the changes in the factors of energy-related per capita CO_2 emissions in China during the years of 2000-2018, with per capita GDP units are million yuan/person. At the same time, energy intensity units are tons of standard coal/million yuan while the carbon coefficient is CO2 tons/energy tons[39].

It can be seen from the table that GDP per capita is rising while energy intensity is decreasing by years. Moreover, there is no huge changes of carbon coefficient since the driving factor (GDP per capita) is greater than the containment factor (energy intensity), the CO_2 per capita in China is rising. According to the factors of influencing the per capita CO_2 emissions in China, we can divided the formula (1) into two branches which are formula (4) and (5) respectively.

$$\text{Per Capita } CO_2 \text{ Emission} = \frac{\text{GDP}}{\text{Population}} \times \frac{CO_2 \text{ Emission}}{\text{GDP}} \qquad (4)$$

$$\frac{CO_2 \text{ Emission}}{\text{GDP}} = \frac{\text{Energy Consumption}}{\text{GDP}} \times \frac{CO_2 \text{ Emission}}{\text{Energy Consumption}} \qquad (5)$$

As it shown above, the formula (5) is a two-factor breakdown, i.e. GDP per capita and carbon intensity. Besides, carbon intensity can also be broken down by another two factors formula (5) which are energy intensity and carbon coefficient accumulation[17].

Finally, the increment Δz of the variable volume of z can also be expressed as the combination of the increment of x as Δx and the increment of y as Δy, i.e:

$$\Delta z = x \cdot \Delta y + y \cdot \Delta x + \Delta x \cdot \Delta y = X_{ef} + Y_{ef} \tag{6}$$

$$X_{ef} = y \cdot \Delta x + \frac{1}{2} \cdot \Delta x + \Delta y \quad \text{and} \quad Y_{ef} = x \cdot \Delta y + \frac{1}{2} \cdot \Delta x \cdot \Delta y \tag{7}$$

3.2 VENSIM model of factor decomposition

We firstly apply the factors from the above formations (6) and (7) into the basic VENSIM elements and then make them into ta table as table 5:

Table 7, VENSIM elements display

Variable	Definition	Variable	Definition
X_{ef1}	per capita GDP utility	X_{ef3}	resources intensity utility
y_1	annual growth of GDP per capita	y_3	annual increase in energy intensity
Δ_{x1}	CO_2 intensity	Δ_{x3}	CO_2 emission coefficient
Δ_{y1}	annual GDP growth per capita	Δ_{y3}	energy intensity annual increase
Y_{ef2}	CO_2 intensity effect	Y_{ef4}	CO_2 emission utility
x_2	CO_2 intensity change	x_4	energy intensity
Δ_{y2}	per capita GDP	Δ_{y4}	annual variation of CO_2 coefficient
Δ_{x2}	CO_2 intensity change×annual	Δ_{x4}	energy intensity annual increase

The flowchart (Diagram) of this model is based on the fundamentals of factor decomposition that is shown in Figure 1, where all the stock is marked as a rectangular small square in the flowchart, and all traffic labels are shown as a pipe with arrows. The per capita CO_2 is designed as a stock (level) and its increment is represented by flow. Moreover, according to the public Formula (6), we break down the per capita CO_2 into two factors, one per capita GDP and the other carbon intensity, all of which are designed as a stock. In addition, the annual increase of CO_2 per capita (that is, the flow of CO_2 per capita) is equal to the sum of the utility of GDP per capita and the utility of carbon intensity.

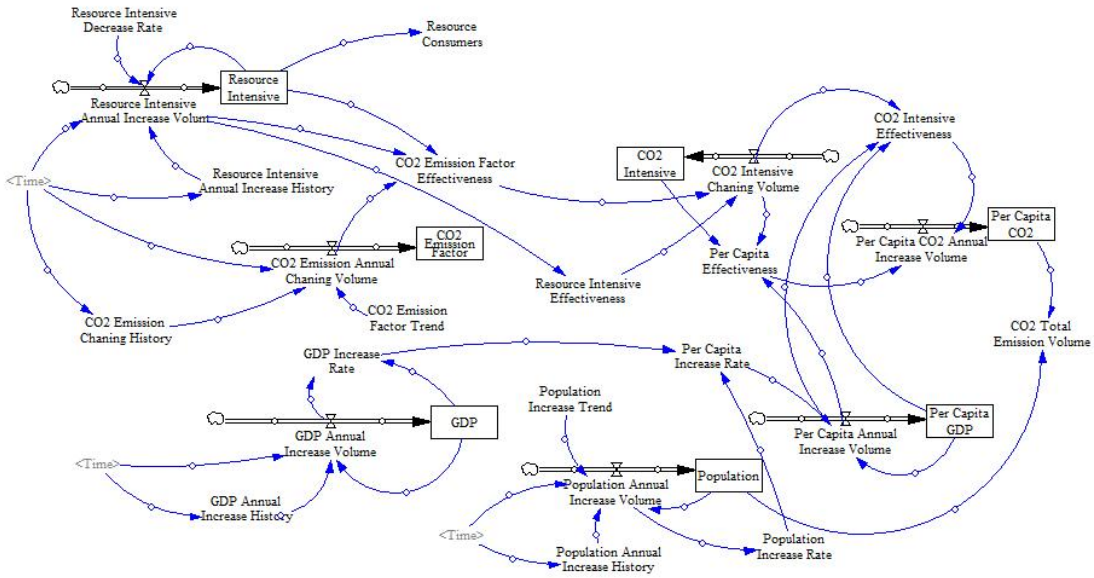

Figure1. The Vensim model for factors of decomposition

3.3 The settings of Venism model

The initial GDP= 168.973 billion yuan

The initial population= 14 billion

The initial value of energy demand=303891 million ton

CO_2 emissions= CO_2 emissions per unit of energy * energy consumption needs

Per unit of CO2 emissions=INTEG (Changes in CO2 emissions per unit of energy, The initial value per unit of CO2 emissions)

The initial value per unit of CO2 emissions=2.5484 million tons/million tons of standard Coal

Investment in fixed assets in the first industry=WITH LOOK UP(
Time,
([(2008,0),(2020,200)],(2008,11.61),(2009,13.99),(2010,16.1),(2011,17.62),
(2012,20.72),(2013,24.35),(2014,28.63),(2015,33.66),(2016,39.57),
(2017,46.52),(2018,54.69),(2019,64.3), (2020,75.59))

Investment in fixed assets in the secondary industry=WITH LOOK UP(
Time,
([(2008,0),(2020,4000)],(2008,142.41),(2009,161.37),(2010,190.97),(2011/22.87),
(2012,262.1),(2013,308.1)(2014,362.1),(2015,425.72),(2016,500.48),(2017,588.4),
(2018,691.71),(2019,813.2),(2020,956.01))

Investment in fixed assets in the tertiary industry=WITH LOOK UP(
Time,
([(2008,0)・(2025,4000 几(2008,112.6),(2009,159.69),(2010,227.3),

(2011,248.9),(2012,292.7),(2013,344.1),(2014,404.5),(2015,475.6),
(2016,559.1),(2017,657.3),(2018,772.73),(2019,908.44),(2020,1067.9))

GDP=INTEG(GDP growth, Initial GDP)
Units: billion yuan

GDP growth=Initial GDP * GDP growth rate

GDP growth rate=0,09

Energy consumption demand=INTEG (Energy consumption demand variable, initial value of energy demand

The growth rate of energy consumption=The rate of GDP growth *(1-SQRT(structural adjustment factors*elasticity of energy demand*per capita GDP influence factor*carbon intensity influence factor))

Carbon intensity influence factors=IF THEN ELSE(the difference between the intensity of carbon emissions and the target value≧0, 0.5, 0.1)

Per capita GDP influence factor=IF THEN ELSE(The difference between GDP per capita and the target/GDP target per capita≧0, 0.5, 0.1)

Elasticity of energy demand=0.5

Energy consumption in the first industry=the output value of the first industry * the energy intensity of the first industry

Energy intensity in the first industry=0.348-(1.0172*the investment of fixed assets in the first industry/the output value of the first industry)-3.0139 * science and technology investment

Energy consumption in the secondary industry =the output value of the secondary industry * the energy consumption intensity of the secondary industry

Energy intensity in the secondary industry=1.658-1.304 * fixed asset input/secondary industry output value of the secondary industry-33.074 * science and technology investment

Energy consumption in the tertiary industry=the output value of the tertiary industry * the intensity of energy consumption in the tertiary industry

The intensity of energy consumption in the tertiary industry=0.518-0.104 * fixed asset investment in the tertiary industry/value of the tertiary industry-9.074 * science and technology investment

Coal demand=energy consumption demand * coal as a proportion of energy

Oil demand=energy consumption demand * the share of oil in energy

Demand for natural gas=energy consumption demand * natural gas as a proportion of energy
Electricity demand=energy consumption demand * the proportion of electricity to energy

Coal accounts for the proportion of energy=WITH LOOK UP(
Time,
([2008,60)▪(2020,80)],(2008,74.1),(2009,74.7),(2010,75.1),(2011,74.7),
(2012,74.9),(2013,75.5),(2014,76.5),(2015,76.9),(2016,76.8),(2017,77.7),
(2018,78.7),(2019,78.3), (2020,77.8))

The share of oil in energy=WITH LOOK UP(
Time,
([(2008,10),(2020,25)],(2008,22),(2009,21.7),(2010,21.5),(2011,21.8),
(2012,21.6),(2013,21.1),(2014,20),(2015,19.7),(2016,19.9),(2017,19.6),
(2018,19.4),(2019)8.3),(2020,17.4))

Natural gas accounts for the proportion of energy=WITH LOOK UP(
Time,
([(2007,0),(2026,4)],(2008,2.4),(2009,2.2),(2010,2.1),(2011,2.1),(2012,2.1),
(2013,2),(2014,2),(2015,2),(2016,2.1),(2017,2),(2018,2.2),(2019,2.3),
(2019,1.9),(2020,2.1))

Birth rate=WITH LOOK UP(
Time,
([(2006,0.00812),(2020,0.012)],(2008,0.010101),(2009,0.01021),(2010.24,0.0107237),(2011.05,0.0107067),(2012.08,0.0109789),(2013,0.01011),(2014,0.01021),(2015,0.01031),(2016,0.01011),(2017.17,0.0104174),(2018,0.01008),(201 &97,0.0104514), (2020,0.01007))

Death rate=WITH LOOK UP(
Time,
([(2006,0.00812)-(2020,0.012),(2008,0.0103),(2009,0.0062),(2010,0.0065),(2011,0.007),
(2012,0.006),(2013,0.0062),(2014,0.006),(2015,0.0061),(2016,0.005),(2017,0.006),(2018,0.006),(2019,0.0065), (2020.04,0.006507))

GDP per capita=GDP/total population

Total population=INTEG (population growth - population decline)

INITIAL TIME=2018 (year)

TIME STEP=1(year)

3.4 The stimulating results

3.4.1 GDP

Through the simulation of a city's carbon emission system, the paper can obtain the GDP simulation data of a city from 2018 to 2030 as follow:

Table 8, The simulation results of GDP from 2018 to 2030

Year	2018	2019	2020	2021	2022	2023	2024
GDP	1572.64	1929.6	2301.93	2692.18	3151.46	3658.84	4191.89
Year	2025	2026	2027	2028	2029	2030	—
GDP	4750.86	5336.96	5969.32	6671.97	7420.94	8018.15	—

（GDP units：billion yuan）

The growth rate of total carbon emissions has slowed significantly. Carbon emissions in the next phase are growing at less than half or less of the previous stage. Hong Kong, the Netherlands, Ireland, Portugal and Sweden are growing at less than half the rate of the previous period. Population growth has slowed. The population growth rate in the next phase is lower than in the previous period.The intensity of emissions has changed from an increase to a gradual decrease, with a much smaller increase than in the previous phase.The rate of economic growth has accelerated significantly. The rate of economic growth is lower than that of the previous period, with other countries or regions growing at 1-2 times the rate of the previous stage and Portugal growing at more than four times the rate of the previous period. The growth rate of carbon emissions per capita has slowed significantly. With the exception of Hong Kong, Ireland, the Netherlands and Portugal, where per capita carbon emissions grew slightly faster than the previous period's 50%, growth in other countries or regions has been significantly reduced[40].

3.4.2 The output value of various industries

Through the simulation of a city's carbon emission system, we get the simulation data of each industry in a city from 2018 to 2030

Table 9, The simulation results of the output value of the first industry from 2018 to 2030

Year	2018	2019	2020	2021	2022	2023	2014
The output value	149.366	154.35	170.5	127.21	11&25	179.1	127.42
Year	2025	2026	2027	2028	2029	2030	—
The output value	110.1	169.71	183.9	195.13	211.3	239.4	—

(The output value units: billion yuan)

With the development of economy, China's industrial structure has been further adjusted and optimized, which shows that the proportion of the value of the first industry has decreased, from 28.2% in 1978 to 11.3% in 2018, a decrease of 16.9 percentage points. The proportion of output value of the tertiary industry increased from 23.9% in 1978 to 40.1% in 2008, an increase of 16.2 percentage points. Status has not wavered, in the secondary industry, industry occupies a dominant position, the proportion of GDP between 36.6% to 44.1%, since 2012 the proportion gradually increased, to reach 42.9% of China's industrial structure in 2018.

Table 10, The simulation results of the output value of the second industry from 2018 to 2030

Year	2018	2019	2020	2021	2022	2023	2024

The output value	1424.5	1418	1556	1761	9177	1765	1914
Year	2025	2026	2027	2028	2029	2030	—
The output value	2119	2313	2437	2544	2660	2789	—

(The output value units: billion yuan)

At present, compared with the world-wide energy consumption hierarchy, China's energy consumption hierarchy still has a great scope for development coordination. Oil accounts for 18.8 percentage points of total energy consumption, 34.8 percentage points globally, China is 16 percentage points lower than the world, and natural gas accounts for 3.6 percentage points, compared with the global level. 20 percentage points lower than the ratio, while coal consumption accounted for 70.2 percentage points, 41 percentage points higher than the global level, nuclear power accounted for less than 1 percentage point, and the global relative level reached 5.5 percentage points. The proportion of energy consumption hierarchy in China is obviously unreasonable, and the proportion of each energy source needs to be changed constantly.

Table 11, The simulation results of the output value of the second industry from 2018 to 2030

Year	2018	2019	2020	2021	2022	2023	2024
The output value	690.25	820.6	857.755	1071.9	1134.04	1197.06	1311.07
Year	2025	2026	2027	2028	2029	2030	—
The output value	1320.54	1206.41	1211.24	1242.5	1266.07	269.4	—

(The output value units: billion yuan)

In terms of the total energy consumption and composition of Table 3 and 5, the total energy consumption continued to grow, with an average annual growth rate of 6.8%, and the share of coal decreased from 70.8% in 2015 to 68% in 2011, but the decline was not very large, 2011 year was 0.4 percentage points higher than in 2010, the share of oil fell from 19.8 per cent in 2005 to 17.9 per cent in 2019, a decrease of 1.9 percentage points, and the share of natural gas was small but stable. increased to 5% in 2011, while the share of hydropower, nuclear power and wind power increased year by year from 2007 to 2011, from 6.8% in 2015 to 8% in 2011, an increase of 1.2 percentage points. Although coal consumption as a proportion of total energy consumption has decreased, but the energy consumption structure is still coal-based structure, which is insopenth with China's energy production structure. It can be seen that China's future will still be mainly coal consumption.

3.4.3 CO_2 emissions

Through the simulation of a city's carbon emission system, the paper obtains the carbon dioxide emissions for each year from 2018 to 2030 volume simulation data

Table 12, The Simulation results for CO_2 emissions 2018-2030

Year	2018	2019	2020	2021	2022	2023	2024
CO_2 emissions	9426.26	10000.9	10795.7	12620.2	12889.8	12980.1	13840.1
Year	2025	2026	2027	2028	2029	2030	—

CO_2 emissions	14361.9	14174.9	14005.2	13734.9	13328.9	12741.2	—

(CO_2 emissions unit: million tons)

Population is the main driving force of economic development and all-round development of society in a geographical area, and it is also a key factor of social development[64]. With the birth rate greater than the mortality rate, rapid population growth, environmental problems are becoming more and more obvious, human technology is far from keeping up with population growth, and greenhouse gas emissions are increasing, in a certain historical period and a certain level of science and technology, the environment itself.

3.4.4 Carbon intensity

Through the simulation of a city's carbon emission system, the paper obtains the carbon intensity model data for each year from 2018 to 2030.

Table 13, Carbon intensity simulation results for 2018-2030

Year	2018	2019	2020	2021	2022	2023	2024
Carbon Intenisty	4.70676	4.54204	4.49634	4.85369	4.6047	4.32898	4.32832
Year	2025	2026	2027	2028	2029	2030	—
Carbon Intenisty	4.22818	3.94203	3.69046	3.43877	3.17864	2.90073	—

(Carbon intensity units: million tons/billion yuan)

3.4.5 Energy consumption demand

Through the simulation of a city's carbon emission system, the paper obtains the energy consumption demand simulation data of a city's energy consumption from 2008 to 2020

Table 14, Results of energy consumption demand simulation 2018-2030

Year	2018	2019	2020	2021	2012	2023	2024
Energy consumption demand	3215.76	3656.88	4404.84	3558.98	3561.65	5778.25	4383.84
Year	2025	2026	2027	2028	2029	2030	—
Energy consumption demand	4023.79	6566.1	7509.13	8385.75	9533.37	11314.1	—

(Energy consumption demand units: million tons)

The purification capacity is limited, the population is too large will inevitably increase the pressure of the environment, it can be seen that advanced science and technology on the reduction of carbon emissions has a vital role. Advanced low-carbon technology is based on low energy, low pollution, low emission and high efficiency, energy conservation and resources of technological innovation model, the goal is environmental protection and energy conservation and emission reduction. Low-carbon technology innovation has realized the transformation from industrialized economy to knowledge-intensive economy, and will certainly become a booster to coordinate the relationship between man and nature and promote the all-round development of economy, society and man. Low-carbon technology innovation is not the same as a single economic benefit, its premise is a steady increase in the economy, the purpose is to coordinate the ecological environment, reduce carbon emissions, but also the inherent needs of sustainable development.

3.4.6 Total population

Through the simulation of a city's carbon emission system, the paper obtains the total population model data of a city's 2018-2030.

Table 15, Simulation results of the total population from 2018 to 2030

Year	2018	2019	2020	2021	2022	2023	2024
Population	655.337	660.237	665.238	670.342	680.715	685.834	690.906
Year	2025	2026	2027	2028	2029	2030	—
Population	695.928	700.977	706.065	711.194	716.364	721.979	—

(The total population unit: million)

The total investment in fixed assets of the whole society in 2011 was 3114.851 billion yuan, an increase of 23.8% over the previous year, of which 875.78 billion yuan was invested in the tertiary industry, an increase of 28.7% over the previous year, and 13.24767 billion yuan was invested in the secondary industry. This is an increase of 27.1% over the previous year, investment in the tertiary sector was 1702.506 billion yuan, an increase of 21.1% over the previous year, and investment in fixed assets is crucial to economic growth. To establish a linear regression model with GDP as the factor and other quantifiable influence factors as explanatory variables to empirically analyze the changes in GDP growth and its main factors.

3.5 Model validity test

The main purpose of testing the validity of the model is to test whether the information obtained by the model can accurately reflect the change law of the system. Through a comprehensive analysis and accurate grasp of the population, economy, energy and mitigation situation related to the carbon emissions of various industries in a city[41].The paper draws on the relevant models, analyzes the specific problems of each industry carbon emission system in a city, establishes the structure of this model in the course of continuous commissioning and operation, and the system dynamics model includes visual detection, testing methods for model effectiveness, historical operation testing and sensitivity analysis[42].

3.5.1 Intuitive inspection

Intuitive test is to test the variable setting and causality of the system model through the in-depth analysis of the existing data whether the system, flow chart structure and equations are expressed correctly[43]. Through a comprehensive analysis and accurate grasp of the population, economy, energy consumption and environmental conditions related to various industries in a city, the paper draws on the relevant models, analyzes specific problems in specific applications, and finally establishes the model structure in the process of continuous debugging and operation. With Vensim software, the scale consistency and table correctness of equations can be realized directly, and the model boundaries are tested to prove that the model is feasible.

3.5.2 Historic test

The historical test selects a historical moment to simulate the system for the initial point, obtains the simulation results and tests the existing historical data. The imitation Allah of the process of carbon emission system in various industries in a city should start with the four indicators of CO_2 emissions, GDP, total population and energy consumption demand, and verify the fit degree of the system model and total allocation. The results are as follows:

Table 16, Historic test results for carbon emissions

Year	Carbon Emissions	Stimulating Values	Deviation
2018	9426.26	9426.26	0.00%
2019	9742.18	10000.9	2.64%
2020	10236.35	10795.7	5.46%

Table 17, Historic test results for GDP

Year	GDP	Stimulating Values	Deviation
2018	1572.64	1572.64	0.00%
2019	2102.45	1929.60	&22%
2020	2428.32	2301.93	5.21%

Table 18, Historic test results for total population

Year	Total population	Stimulating Values	Deviation
2018	655.337	655.337	0.00%
2019	686.53	660.237	3.83%
2020	690.74	665.238	3.69%

Population is a key factor in the comparison of population and resources, and development is at the forefront. In the relationship between environment and development, the change of population quantity will also cause a series of changes between the two. Controlling the rate of population development that is appropriate to the level of production development is an important aspect of systematic development. Through table 5-11, it can be clearly seen that a city's population factor simulation is better, the error is within 10%, the effect is more ideal, that is, a city's carbon emission system of the population factors through the historical test.

Table 19, Historic test results for energy consumption

Year	Energy Consumption	Stimulating Values	Deviation
2018	3218.76	3218.76	0.00%
2019	3256.21	3656.88	9.5%
2020	4103.43	4404.84	7.35%

Judging from the results of historical tests, the simulation values and historical values are basically consistent, in the system of 4 variables in each year, the relative error is less than 10%, the model simulation results and the actual results meet the fit requirements, confirming that the model built by the thesis can really reflect the actual situation. For space reasons, the historical tests of other variables are similar, and there is no longer much to explain here.

3.5.2 Sensitivity analysis

Sensitivity analysis is the change of some parameters in the model, the influence on the whole system is by the output operation mode and comparison model, sensitivity analysis includes the structural sensitivity analysis of parameter sensitivity analysis[44].

1) Parameter sensitivity analysis, mainly to study the model behavior in the model for parameter value change sensitivity. Set the change parameter to X, the output variable to Y, sensitivity S to analyze, and the expression to use S (O Ay (O/AX (O-in-line).

2) Structural sensitivity analysis refers to the analysis of the effect of changes in causal type on model action behavior. That is, by observing the behavior of the model. Identify the basic principles of system operation and discuss and analyze the causality of objections. It is studied that the system model established in this paper has clear causality and no objection.

In conclusion，by testing the carbon emission system of a city, the results show that: For the structure of the model, the paper finds in the test process of the model that most of the parameter value changes in the model will only cause the trend change of the results, will not lead to the fundamental change of the system behavior. These paper models are insensitive to changes in most parameters and are effective. The results show that from the visual inspection and operation inspection analysis model, historical test and sensitivity can reflect the real system, can be used to guide and support the simulation model.

4. Carbon emissions system scenario simulation

The Chinese government has reconsidered and adjusted its development policies every fifth year since 1953, called the Five Year Plan, to control its socio-economic development[45]. The time span of scenario assumption in this study ranges from 2007 to 2020, which covers the period of China’s 12th Five-Year Plan. With 2007 as the base year, the stages of scenario prediction are divided into the short-term step and long-term step in accordance with this Five-Year Plan[46]. The strategic and development targets in the 12th Five-Year Plan are considered to be the key reference for scenario assumptions and parameters design. The economic implications of the factors affecting changes in carbon emissions.

In the face of climate change, the development of a low-carbon economy, can not be separated from the stage of development. At different stages, the priorities and objectives of developing a low-carbon economy should be different. In the early stages of a country's or region's development, emphasis should be placed on reducing carbon intensity or increasing carbon productivity[47]. Realistically, developed countries should focus on per capita and aggregate emission reduction targets, while developing countries should aim to increase carbon productivity or reduce carbon intensity[48]. Under the condition of low income level, if developing countries take on the reduction of total greenhouse gas emissions too early, it will not only violate the law of development, but also hinder development, and it will also be unfair[49]. Developed countries, as major emitters of greenhouse gases, should increase technology transfer and financial support to developing countries when they assume the same obligations to reduce greenhouse gas emissions, so as to help developing countries leapfrog the three peaks of carbon emissions in a relatively short period of time and at lower levels of development.

Reducing the growth of carbon emissions can reduce the growth rate of population, economic growth rate, carbon intensity or energy intensity and carbon emissions per unit of energy[50]. Because of the great sustainability of population growth, it is difficult to achieve significant results in the short term, but it cannot be allowed to flow. Especially for developing countries with faster population growth, strict measures, such as family planning measures, should be taken to limit the excessive growth of the population, which will play a positive role in improving the quality of life of residents, mitigating carbon emission growth and promoting global sustainable development[52-53]. To reduce energy intensity and carbon emissions from single-bit energy sources, we should increase the intensity of technological innovation and policy innovation, give full play to the system's action and regulation, adjust the economic structure, restrict the export of energy-intensive products, vigorously develop low-carbon or renewable energy sources and optimize energy structure, adopt economic incentives and strict technical standards to promote energy conservation, improve relevant laws and regulations, strengthen supervision and management, promote close partnership between governments, enterprises and the public in the field of energy conservation and emission reduction, and develop good governance structure[554-55]. We will vigorously develop and apply technologies such as energy conservation, energy efficiency, carbon reduction and carbon dioxide capture and storage (CCS), strengthen international cooperation in the field of carbon reduction or climate change, and actively seek technology transfer and financial support from developed countries[56].

In order to understand the changes in the influence factors of carbon emissions in developed economies and representative developing countries at different stages, the IPAT equation (1) of carbon emissions can be analyzed. The IPAT equation was originally proposed by Ehrlich and other scholars to show the environmental impact of economic development or the causes of environmental problems, i.e. the result of a combination of population, wealth and technological factors[35].

If CO_2 emissions are used to represent environmental impacts, the environmental impact equation (see equation 3-14) becomes an IPAT equation for carbon emissions, transformed into a Kaya model with an expression of:

$$\mathrm{CO}_2 = P * (GDP/P) * (E/GDP) * (CO_2/E) \qquad (8)$$

E/GDP represents energy intensity, mainly related to technology, and CO2/E is related to energy utilization structure.

Carbon-intensive technologies play a leading role in carbon emissions in the lead-up to peak carbon intensity. When carbon intensity peaks at the peak of per capita carbon emissions, GDP per capita or economic growth dominates carbon emissions. While technological advances can mitigate carbon emission growth, they cannot offset the rise in total carbon emissions due to population and economic growth, with only a few countries, such as New Zealand and Brazil, leading the way[57].

When the difference between the peak per capita carbon emissions and the peak of total carbon emissions is not significant, the effects of technological progress are obvious, and gradually offset the effect of population and economic growth on carbon emission growth[58]. Carbon emission growth is significantly slowing towards zero growth. After reaching the peak of total carbon emissions, low-carbon technological progress will occupy an absolute leading position for a long time, and the total carbon emissions will further develop in a steady decline direction, thus achieving a complete decoupling of economic growth from carbon emissions[59].

According to the current situations in China, the first scenario is the "baseline scenario", that the government declared that China's economic transformation during the Twelve-Five period, the economic growth rate was reduced to 7%, but the local governments still do not forget the high increase long-term benefits while the whole society is still in the economic circle of "strong" carbon emission increase factors.

Table 20, The table of analyzing influencing factors and Data

Year	Per capita CO_2	Per capita GDP	Energy Intensive	Carbon coefficient
2000	1.93	0.3773	2.2883	2.2356
2001	2.01	0.4066	2.2038	2.2432
2002	2.07	0.4592	2.0292	2.2217
2003	2.22	0.5173	1.8918	2.2683
2004	2.29	0.5785	1.7703	2.2361
2005	2.47	0.6350	1.7056	2.2807
2006	2.59	0.6913	1.6423	2.2813
2007	2.51	0.7480	1.4902	2.2519
2008	2.53	0.7992	1.3259	2.3874
2009	2.43	0.8531	1.2471	2.2839
2010	2.40	0.9181	1.1907	2.1954
2011	2.42	0.9874	1.1363	2.1568
2012	2.58	1.0701	1.1043	2.1832
2013	2.97	1.1704	1.1570	2.1933
2014	3.50	1.2809	1.2206	2.2387
2015	3.88	1.4602	1.2220	2.2580
2016	4.27	1.5539	1.2061	2.2785
2017	4.57	1.7487	1.1495	2.2736
2018	4.90	1.8964	1.1318	2.2830

(Data Resources are from IEA)

The second scenario is the "reduction scenario", where many regions no longer compare the growth rate, the performance of local governments and the economic growth rate has been reduced to 7%, energy intensity has declined at a rate of 5%, and enterprises Production embarked on "energy saving and carbon reduction".

The third scenario is the "limited scenario", after the Confucian philosophy of harmonious development of the people has gradually taken root in this situation, in which CO_2 is not a reduction problem but a limit problem. Energy tax and carbon tax are on the road which means GDP growth rate reduced to 6.5% and energy intensity will decline at a rate of 5.5%.

Based on the Vensim Model, the GDP variable is designed as a stock, its historical data is used as a table function, the future changes with external parameters, and the initial value of GDP is 2000 of 4.3134 trillion Yuan and the data after 2018 changes due to the situation. The remaining variables, such as energy intensity, carbon coefficients, population and other variables are designed and calculated in the same way as GDP[48-49].

5. Results

5.1 CO_2 and CO_2 emissions per capita

Under the the first 'baseline scenario', we set the initial time as 2010 and the final time is 2030. It is shown that CO_2 emissions increased from 7.19 billion tons in 2010 to 8.12 billion tonnes in 2030, growing by 1.73tons. The average annual growth rate of 2.77% per capita CO_2 emissions grew from 2010 per person 5.4 tonnes to 8.4 tonnes in 2030 which is 1.56 times times longer, with an average annual growth rate of 2.22%.

Additionally, in the second 'reduction scenario' the total CO_2 emissions in 2030 is about 1.38 times times that of 2010 with the average growth rate of 1.16%.

Finally, in 2030 per capita emissions account for about 6.6 tonnes CO_2 with an average growth rate 1.1% in the third 'limited scenario'. Furthermore, the total per person CO_2 emissions are 5.5 tons while the annual growth rate of 0.02% in 2030 which is 1.15 times than201.The amount of total CO_2 emissions per capita CO_2 emissions for each scenario is shown in table 13.

Table 21, Total CO_2 emissions per capita and total CO_2 emissions in each scenario

	Per captia CO_2 Emissions (ton/person)			Total CO_2 Emissions (million tons)		
Year	baseline scenario	reduction scenario	limited scenario	baseline scenario	reduction scenario	limited scenario
2005	3.9240	3.9240	3.9240	513094	513094	513094
2010	5.3593	5.3162	5.3593	718909	713132	706058
2015	5.9757	5.5623	5.2388	821847	764989	720498
2020	6.6357	5.9677	5.3475	935654	841469	754012
2025	7.3767	6.1752	5.4082	1066408	892715	781835
2030	8.3861	6.6433	5.4806	1242933	984638	812309

According to the simulation results, the total amount of CO_2 emissions under the baseline scenario increased from about 5.36 billion tons in 2010 to 8.39 billion tons in 2030, growing with the average annual growth rate of 7.76%. Secondly in the reduction scenario, the per capita CO_2 emissions grew from 2010 for 5.32 tonnes to 6.64 tonnes in 2030 with an average annual growth rate of 2.22%. Lastly, under the limited-limit scenario,the total CO_2 emissions in 2030 will be about 1.15 times that of 2010, with an average growth rate of 0.7% increase to about 5.5 tons eventually.

5.2 Carbon intensity

The whole simulated results are illustrated in table 10, that the carbon intensity is equal to the product of energy intensity and carbon coefficient, the source of carbon intensity decline is the decline of energy intensity. In 2010, every 10,000 yuan of GDP was generated to emit 2.76 tons of CO_2. Since the government wants the carbon intensity to fall to in 2030. Therefore, in baseline scenario the carbon intensity is of 1.53 tons per million yuan of GDP in 2030 which is equivalent to 2005 of 55%; Moreover, In 2030, the carbon intensity of 1.46 tons per million of GDP is equivalent to 53% of 2005 under reduction scenario. Finally, in limited scenario, the carbon intensity of 1.38 tonnes per million in 2030 which as equivalent to 50% in 2010. From this perspective, this model expresses the government's vision of carbon reduction.

Table 22, Total carbon intensity in each scenario

	CO_2 Intensity (ton/million yuan)		
Year	baseline scenario	reduction scenario	limited scenario
2005	2.762328	2.762328	2.762328
2010	2.427501	2.421518	2.408871
2015	1.916544	1.857555	1.799804
2020	1.534267	1.461689	1.379589
2025	1.232828	1.131085	1.053504
2030	1.002299	0.892133	0.804589

From the table of carbon intensity, it can be reflected that, in 2005, the average statistic was that when generating 10,000 yuan of GDP it would produce around 2.76 tons of CO_2. Under the baseline scenario, while the carbon intensity of 1.53 tons of GDP per 10,000 yuan in 2020 is equivalent to 55% of 2005, however, the rate could be much lower in 2030 which may account for about 276%. In addition, the carbon intensity of 1.46 tons of GDP per 10,000 yuan in 2020 is equivalent to 53% of 2005 under the time of second scenario. Finally, the limited scenario showed that carbon intensity of 1.38 tons of GDP per 10,000 yuan is equivalent to 50% of 2005. From this point of view. This model expresses the government's vision for carbon reduction.

6. Discussion

China's total energy consumption will be in continuous growth in future decades, and rapid economic growth will inevitably stimulate a large energy demand so as to promote the growth of total energy consumptions. However, the growth rate of total energy consumptions will be restricted to some extent under each scenario, due to energy conservation and emission reduction policy as well as low carbon technology[73].

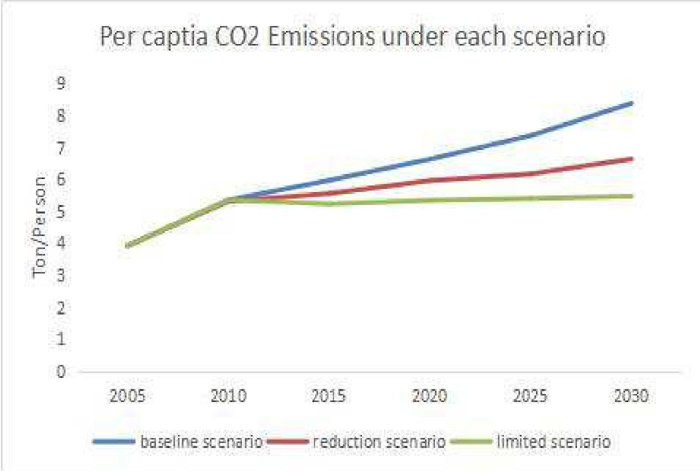

Figure 2, The per captia CO_2 emissions under each scenario

It can be conducted from the two line graphs that they both illustrated almost the same trend in the further decade. Fist of all, the forecast indicates that total CO_2 emissions will rise under three scenarios as a whole for the first 5 years. After 2010, they tended to be in different climbing rate, even though they still kept increasing, however, it is obvious that either the per captia CO_2 emissions or the total CO_2 emissions under the baseline scenario are predicted to expand more tremendously than the other two scenarios which may experience about a twofold increase from both two graphs. On the contrary, the volume under the limited scenario seemed to be the lowest one that the data of per capta emissions would possible increase from 4 ton/person to about 5 ton/person, meanwhile, the total emissions ascend less than 200000 million tons as well. Therefore, the limited scenario could be the best choice in order to lower the CO_2 emissions in China in the further decade.

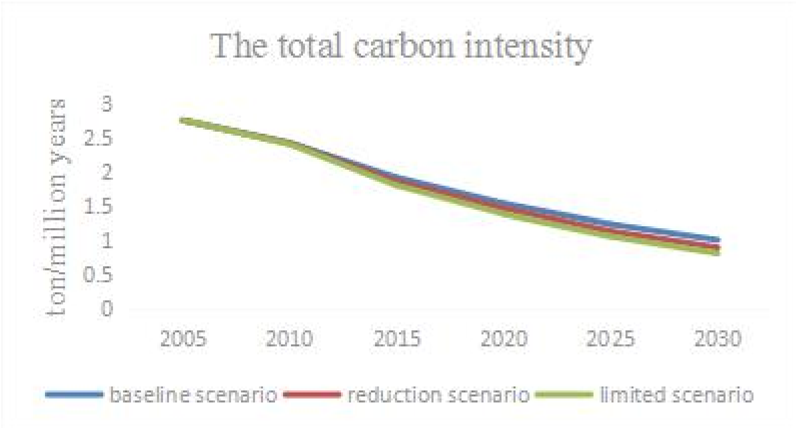

Figure 3, The total carbon intensity under each scenario

Furthermore, the carbon intensity does not indicate high efficiency. In general, carbon intensity indicators are reduced as technology advances and economic growth. Low intensity does not indicate high efficiency. Poor agricultural countries have low carbon intensity, but are not efficient; For example, a product is equally energy efficient, but not all sold and not realized by currency. In general, strength indicators, both developed and developing, decline over time (technological progress and economic growth). The commitments made under this natural downward trend are meaningless; Because capital, technology, etc. are scarce resources. For developing countries, if financial and technological security is available, intensity commitments are desirable in the near term; Thus, in the long term, it may be detrimental to developing countries.

As it is demonstrated from the line graph that all the three lines showed a downward trend from the original year of 2005 to the final year of 2030 which is consistent with the carbon intensity of developing countries, meanwhile, the declining rate were also similar to each other. However, the line of limited scenario was the lowest which decreased from around 3 ton/million years to less than 1 ton/million years whereas the other two lines were little higher than it and the line of baseline was the highest one as well.

7. Conclusions

As a consequence, the simulation presents that the target of the Chinese government's 2030 carbon intensity falling to 2010 is likely to be achieved. Therefore, if China's per capita emissions sustain an inertial growth of 2010, it will catch up with 16.2 tons of the United States at the year about 2030. Moreover, if China's development still maintains its benchmark scenario, it is possible that China will catch up with the United States for 17 tonnes per captia in the year of 2030. Finally, if China maintains a limited scenario from then, China's per capita carbon footprint will remain below every person of the world which is about 6 tons per captia per year. Therefore, the best proposal for Chinese government is to take the limited scenario that GDP growth rate reduced to 6.5% and energy intensity will decline at a rate of 5.5%.

In conclusion, there are major four paths for China to develop in the future. The initial one is so called the technological innovation. Low carbon technology innovation contributes to the drop in energy intensity to restrict total energy consumption and growth rate of CO_2 emissions and reduce carbon intensity[72]. The carbon emission reduction technology is the driving force to improve energy utilization ratio; the clean utilization of high-carbon energy can be realized if advanced and efficient energy conservation and low carbon technology can be widely applied and relevant policies and measures can effectively promote carbon emission reduction and low-carbon development[73]. China shall integrate technological research & development, policy orientation, economic development and climate change measures, make the best of existing natural resources, emphasize the development, conversion and utilization technology of major clean energy, realize low-carbon utilization of high-carbon energy and ensure that low carbon technology innovation is beneficial for sustainable development of energy and also for harmonious development of the economy[74]. The technological innovation path is applicable to most regions and cities in China, and is especially influential in industrial and resource based cities.

Secondly, the industrial structure optimization. Based on natural resource endowment and other factors, the industry system with resource-based industry in dominance is formed in China[75]. The energy consumption is huge in resource-based industry so that China's industrial structure is featured with high energy consumption and high emission at present. Under LC scenario, Chinese government shall further optimize and adjust industrial structure, appropriately control high-energy consumption industry, positively take measures to promote low-carbon industries in development and gradually form the industrial structure with low energy consumption and high efficiency[75-77]. The industrial structure optimization has a significant influence on China's low-carbon development in the future.

Furthermore, the energy structure optimization. It is difficult to change the energy structure in which coal is dominant and which is formed upon resource endowment in China in a short period.The short-term ''low carbon'' adjustment of energy structure is beneficial for the reduction of CO_2 emissions, but has little influence for low-carbon development, thus, the breakthrough in new energy technology is required[78]. Apart from reasonable mining and processing of fixed energy, Chinese government shall attach importance to new energy and renewable energy to optimize energy structure. In the short term, coal consumption shall be continually reduced, while petroleum and natural gas shall be increased appropriately in consumption[79-80]. In the long term, renewable resources such as wind energy, hydroenergy, bioenergy, solar energy and ocean energy shall be emphasized in the development. It is necessary to shrink the share of coal in energy consumption structure and gradually increase the proportion of new energy and renewable energy in consumption[81]

Finally, as the policy guidance. technical innovation, industrial structure optimization and energy structure optimization have a positive influence on China's low-carbon development, but they must be guided by relevant policy[82]. The government shall improve relevant energy conservation and emission reduction policies by formulating appropriate industrial structure upgrading strategies and adopting a motivation system of low carbon technology innovation in order to form an ideal low-carbon industry system characterized by low energy consumption, high technological content and good economic benefits, and to provide the positive policy orientation for low carbon development in China. This path is the only way for China's sustainable development in the future[82].

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