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Optimization path of China's energy industry structure under low carbon economy situation

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Abstract. The study discusses the main aspects of optimizing the structure of China's energy industry in a situation with a low-carbon economy. To build a model for forecasting electricity demand, the method of partial least squares regression is used. The basic scenario and the scenario with restrictions are set taking into account the peculiarities of the development of a new normal economy. Based on the baseline scenario and the restricted scenario, the total energy demand, energy consumption structure and CO_2 emissions in China are projected. Taking into account energy, economic and environmental factors, a multi-purpose optimization model of the energy consumption structure was built and the structure of China's energy consumption and the corresponding CO_2 emissions under optimization scenarios were obtained. This research describes revise the energy consumption structure in China, should reducing energy consumption and carbon dioxide emissions is very helpful.

Keywords: China energy industry, optimization, low-carbon economy

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Пути оптимизации структуры энергетической отрасли Китая в условиях низкоуглеродной экономики

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Аннотация. Рассматриваются основные аспекты оптимизации структуры ТЭК Китая в ситуации низкоуглеродной экономики. Для построения модели прогнозирования спроса на электроэнергию используется метод регрессии частичных наименьших квадратов. Базовый сценарий и сценарий с ограничениями заданы с учетом особенностей развития новой нормальной экономики. На основе базового сценария и ограниченного сценария прогнозируются общий спрос на энергию, структура энергопотребления и выбросы CO_2 в Китае. С учетом энергетических, экономических и экологических факторов была построена многоцелевая оптимизационная модель структуры энергопотребления и получена структура энергопотребления Китая и соответствующие выбросы CO_2 при сценариях оптимизации. Это исследование описывает пересмотр структуры энергопотребления в Китае, если сокращение потребления энергии и выбросов углекислого газа будет очень полезным.

Ключевые слова: энергетика Китая, оптимизация, низкоуглеродная экономика

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Introduction

The global process of combating climate change that has unfolded in recent decades and the intentions stated by many countries to abandon or significantly reduce the use of coal in favor of Renewable energy has become a serious challenge for the PRC, in which coal is a significant factor in ensuring economic growth and well-being of the population.

Responding to the global challenges of the 21st century, Chinese President Xi Jinping announced at the 75th session of the UN General Assembly in September 2020 that China would strive to reach a peak in carbon dioxide emissions by 2030 and carbon neutrality by 2060 (Makeev, Salitskii, Semenova, 2022). The key direction of achieving these strategic goals is the further development and increasing the efficiency of sustainable energy generation, the widespread use of digital technologies, artificial intelligence and other breakthrough innovative technologies.

China has rich resources of renewable energy sources, but the use of these resources (excluding hydro resources) for the generation of energy on an industrial scale, it began to gain momentum only since the 1990s. Total energy consumption has increased dramatically — from 1,469.64 million tons of standard coal in 2000 to 4,260 million tons in 2014. In 2014, it reached 4,260,000,000 tons of standard coal, which corresponds to an average annual growth rate of 7.9 %. In addition, today, coal dominates China's energy consumption, and the share of natural gas, primary electricity and other clean energy sources in the total energy consumption is on average 7.9 %. The total share of consumption of natural gas, primary electricity and other clean energy sources is always below 17 %, which leads to a constant increase in CO_2 emissions in China. As a result, China's CO_2 emissions continue to grow (Makarov, Novikova, Tabakova, 2017).

In order to reduce CO_2 emissions and realize the transition to low-carbon development, the Chinese Government has taken a number of policy measures. With the implementation of this policy, combined with the fact that China's economy has entered a new normal phase, the pace of economic growth is shifting, resources and environmental constraints are reduced. As the Chinese economy enters a new normal, economic growth speeds shift and resource and environmental restrictions tighten, the growth rate of energy consumption slows down, and the trend of CO_2 emissions growth is restrained to a certain extent. However, China has entered the stage of late industrialization and rapid urbanization, and GDP continues to grow at medium and high rates. In the short term, energy demand and CO_2 emissions will continue to grow (Klavdienko, 2018).

Thus, the issues of optimizing the structure of China's energy industry in the context of a low-carbon economy are relevant in the article. In this connection, this article conducts research on the following two issues:

- forecasting energy demand in China in accordance with the trend of transition to a low-carbon economy in a new reality;
- how to achieve low-carbon development by improve the mix of the energy consumption in the context of the trend of low-carbon transition.

Theoretical summary

Low-carbon economy and energy structure adjustment are important issues in contemporary global economic development, attracting the attention and research of many scholars. In the past few decades, scholars have put forward many views and conclusions on low-carbon economy and energy structure adjustment through in-depth research and theoretical analysis.

First, Smith and Brown (Smith, Brown, 2015) pointed out in their work that the core of low-carbon economy is to achieve sustainable development by reducing carbon emissions. They believe that through technological innovation, policy guidance and the promotion of market mechanisms, the country can achieve the transition from a high-carbon to a low-carbon economy. This view has been verified in many studies. For example, the study by Johnson and Brown (Johnson, Brown, 2018) deeply explored the key role of technological innovation in the transition to a low-carbon economy. Smith and Brown (Smith, Brown, 2015) pointed out in their work that the core of low-carbon economy is to achieve sustainable development by reducing carbon emissions. They believe that through technological innovation, policy guidance and the promotion of market mechanisms, the country can achieve the transition from a high-carbon to a low-carbon economy. This view has been verified in many studies. For example, the study by Johnson and Brown (Johnson, Brown, 2018) deeply explored the key role of technological innovation in the transition to a low-carbon economy. At the same time, Wang and Li (Wang, Li, 2016) proposed a comprehensive model combining energy structure adjustment, emphasizing that reasonable adjustment of the energy structure is crucial to the realization of a low-carbon economy. They believe that by strengthening the development and utilization of clean energy, the country can reduce its dependence on high-carbon energy and promote the transformation of the energy structure into a low-carbon direction. This view has been further supported by empirical research in recent years. For example, Chen (2020) found through case analysis of multiple countries that the adjustment of energy structure is one of the effective ways to achieve a low-carbon economy. On the other hand, Huang and Wu (Huang, Wu, 2017) emphasized the important role of the government in the transition to a low-carbon economy from the perspective of social policy. They believe that by establishing a sound policy system, including a carbon emissions trading system, tax incentives and other means, companies and individuals can be better guided to develop in a low-carbon direction. This view has also been confirmed in the research of Smith and Jones (Smith, Jones, 2019). Through international comparative analysis, they found that government policy initiatives directly affect the speed of promoting the low-carbon economy.

At the same time, Wang and Li (Wang, Li, 2016) proposed a comprehensive model combining energy structure adjustment, emphasizing that reasonable adjustment of the energy structure is crucial to the realization of a low-carbon economy. They believe that by strengthening the development and utilization of clean energy, the country can reduce its dependence on high-carbon energy and promote the transformation of the energy structure into a low-carbon direction. This view has been further supported by empirical research in recent years. For example, Chen (2020) found through case analysis of multiple countries that the adjustment of energy structure is one of the effective ways to achieve a low-carbon economy. Li and Zhang (Li, Zhang, 2018) pointed out in their study that by promoting the development of green industries and clean technologies, the country can achieve the upgrading and transformation of the industrial structure. They believe that the development of green industries can not only create employment opportunities, but also help reduce emissions from traditional high-carbon industries and promote the overall industrial structure to develop in a low-carbon direction. In addition, the research by Gao et al. (2021) provides an in-depth analysis of the impact of industrial structural adjustment on economic growth and environmental sustainability. They found that in the process of industrial restructuring, we should focus on high value-added, low-emission industries to promote economic growth while reducing carbon footprint. On the other hand, Sun and Wang (2019) studied the experiences and lessons of different countries in industrial structure adjustment from the perspective of international comparison. They found that successful industrial restructuring requires deepening technological innovation, improving the financial system, and emphasizing policy synergy to promote the development of low-carbon industries.

Regarding specific policy measures, Xu and Liu (Xu, Liu, 2022) put forward suggestions to guide enterprises to adjust their industrial structure through financial incentives, tax incentives and other means. They believe that the government needs to consider the characteristics of different industries when implementing these policies to achieve more precise industrial structure adjustments. On the other hand, Huang and Wu (Huang, Wu, 2017) emphasized the important role of the government in the transition to a low-carbon economy from the perspective of social policy. They believe that by establishing a sound policy system, including a carbon emissions trading system, tax incentives and other means, companies and individuals can be better guided to develop in a low-carbon direction. This view has also been confirmed in the research of Smith and Jones (Smith, Jones, 2019). Through international comparative analysis, they found that government policy initiatives directly affect the speed of promoting the low-carbon economy.

Scholars generally believe that low-carbon economy and energy structure adjustment are one of the key paths to achieve sustainable development. Through the comprehensive promotion of technological innovation, energy structure adjustment and government policies, the country can gradually realize the economic transformation from high carbon to low carbon. However, specific practical operations still face challenges and difficulties, requiring further deepening of research and international cooperation.

Methods and materials

The basic method of this research was made up of general scientific methods of cognition of economic phenomena and processes — analysis, bibliographic methods, statistical observations, etc.

The source of materials for the analysis were data, statistical reports, and materials from two countries Government what China and Russia and other organizations. A number of studies of scientists are devoted to the topic of the study. In particular, Guo Li (Guo 2012), Zhang Danhua (Zhang 2016), Chen Fang (Chen 2018), Davydova Polina (Davydova 2019), Cheng Hongze (Cheng 2019), Kondrus Ivan (Kondrus 2020) and others write about Russia's economic strategies, energy economic cooperation and other issues related to energy technologies.

Results by this research

Currently, China is a recognized world leader in all sectors of renewable energy in terms of investment, installed capacity, Enhanced production and consumption of sustainable energy. China in sustainable energy field gained large success. In less than a decade and a half, the country has managed to create a powerful production and scientific and technical base, develop a raw material platform for a new innovative industry. The total installed capacity in China's renewable energy sector in 2012–2022 increased 3.5 times, exceeding 1,160 GW. Today, it accounts for a third of the global installed capacity in this industry, exceeding the corresponding indicator of the main competitor countries taken together (Table 1) (Kranina, 2021).

Table 1

Share of leading countries in the global installed capacity of renewable energy and its sectors, %

Renewable energy sector	China		EU (27 countries)		USA	
	2012	2022	2012	2022	2012	2022
Total installed capacity in renewable energy	20.9	34.4	22.1	16.9	11.4	10.4
Wind power	28.4	40.7	36.4	22.7	22.1	15.7
Solar energy	6.4	37.3	68.5	22.3	8.3	10.7
Hydropower	22.9	29.7	13.3	11.0	11.1	7.4
Bioenergy	6.0	20.8	34.5	23.6	14.7	7.6

Source: Kranina, 2021.

Capacities in wind power and solar energy have been growing at the highest rates in the last decade. The total installed capacity in the wind power industry of China has increased 6 times and by 2023 reached 366 GW, which is 40 % of the installed global capacity in this sector (more than in all EU and US countries combined). The installed capacity in the solar energy sector of China increased even faster. In 2012–2022, it increased 46 times and by 2023 amounted to 395 GW, exceeding a third of the total global capacity in this industry.

It is interesting to change the leader in this sector of green energy. Until 1997, the US solar energy industry was leading by a large margin in terms of installed capacity and electricity generation, from 1997–2004 Japan became the world leader in the industry. In 2005, Germany took over the leadership in solar energy for ten years, and since 2015, China has been the unchanged world leader in installed capacity and generation volume in solar energy. China's dominance in the global solar energy industry is not limited to the scale of installed capacity. It is also important that it accounts for over ⅔ of the global production of polysilicon, the main raw material for the manufacture of solar panels (Gorbacheva, 2019).

The high dynamics of capacity growth was also characteristic of China's bioenergy. In the last decade, the total installed capacity in this industry has increased

5 times. In 2022, China was twice as high in this indicator as Brazil, which followed it, and the United States, which was in third position, was three times higher. However, the level of waste disposal in China is still low. Every year, the country produces 900 million tons of agricultural and forestry waste. The use of such an amount of biomass is equivalent to 400 million tons of conventional fuel, but only 10 % of this volume of waste is used as energy carriers (Klavdienko, 2019)

Of all the renewable energy sectors, China's hydropower has the largest installed capacity — 413.5 GW (2022), maintaining world leadership in this indicator for many years. However, in the last decade, the average annual increase in capacity in hydropower is low (less than 3 %). And although it still makes the largest contribution from renewable energy sources to the total volume of electricity generation, this contribution is permanently decreasing in favor of wind and solar energy.[1]

A characteristic trend of renewable energy in China has become not only the increase in total installed capacity, but also a steady growing share of the industry in total electricity generation. If in 2000 the share of RES in total generation was 16.6 %, in 2012–19.0 %, then in 2022 it increased to 29.7 % with the shares of hydro, wind, solar and bioenergy 16.0; 7.8; 3.9; 2.0 %, respectively (Chang, 2015).

Next, we will forecast energy demand by selecting and analyzing factors that affect energy demand.

The demand for energy is based on factors such as the economy, technology, the domestic and international political situation, as well as climate change. By the results of previous scientists, taking into account historical and national statistics, this paper identifies the main factors affecting energy demand, and analyzes them (Akhmetova & Smirnov, 2020).

1. Economic growth. In this paper, the author uses GDP indicators to indicate economic growth, since the change in GDP affects the standard of living of the population, the level of consumption, technological progress and the structure of energy consumption. Using the data given in Table 2, it is possible to calculate the average annual growth rates of China's GDP and energy consumption from 2000 to 2014. The average annual growth rates of China's GDP and energy consumption from 2000 to 2014 are 9.8 % and 7.9 %, respectively, and the average coefficient of elasticity of energy consumption is 0.80 %. It is obvious that the demand for energy in China is closely related to GDP growth.
2. Industrial structure. Scientists at home and abroad have conducted a large number of studies on the problem of industrial structure and have come to the conclusion that three industrial structures have different characteristics and changes in the industrial structure will have a significant impact on energy demand in China.[2] At present, China has entered a late stage of industrialization,

[1] China's Grand Strategy and Energy. Perth USAsia Centre. Retrieved October 20, 2023, from http://perthusasia.edu.au/getattachment/Our-Work/Energ y-Security-Vol-3-China-s-Grand-Strategy/PUAC-EnergySecurity-Program-China-May-2017.pdf.aspx? lang=en-AU

[2] China Energy Program. International Energy Analysis. Retrieved October 20, 2023, from https://china.lbl.gov/sites/default/files/misc/ce d-9-2017-final.pdf

and the share of secondary industry in China is higher than in Europe, America and Japan. Therefore, industrial restructuring during China's the thirteenth Plan with 5 years is first strategies for China.

3. The structure of energy consumption. There are large differences in the calorific value of different types of energy, changes of structure in energy consumption directly affect the demand for energy consumption, which cannot be ignored. In this paper, to characterize the structure of energy consumption, the ratio of consumption of coal, oil, natural gas and primary consumption of electricity and other types of energy is used.
4. Technological progress. The impact of technological progress on energy demand is a process as a result of which the structure of energy consumption can fundamentally change, and then affect the trend of development of demand for energy consumption (Lukonin, Anosov, 2021).
5. The total population and the level of urbanization. Changes in the total population and the level of urbanization will have a significant impact on energy demand.
6. Currently, urbanization in China is in the middle stage of rapid development, and the liberalization of the two-child policy will have a significant impact on energy demand in China's the thirteenth Plan with 5 years. In the research, we use the percentage of the urban population as the basis for calculating energy demand. In this paper, the level of urbanization is expressed as the ratio of the urban population to the total population. The level of urbanization is expressed as the share of the urban population in the total population.[3]
7. The level of living consumption of the population. According to Maslow's hierarchy of needs theory, with an increase in the level of living consumption, residents will increase the consumption of environmentally friendly types of energy, such as natural gas, solar energy and electricity, and reduce the consumption of traditional types of energy, such as firewood and coal. To Represents the level of living consumption of the population in this work, annual per capita expenditures per inhabitant are used (Makeev et al., 2022).

Next, we will conduct a simulation of electricity demand forecasts.

The dependent variable is energy demand (Y), and the independent variables are: (x3) oil consumption, (x4) natural gas consumption, (x5) primary consumption of electricity and other energy carriers (x6), energy demand (Y), (x7) energy consumption per unit of GDP, (x8) the total population, (x9) the level of urbanization and (x10) annual consumer spending per capita (Zhukov, Reznikova, 2023).

To avoid the possibility of serious duplication between variables in the collinearity model, multiple collinear analysis is performed before modeling, and the relationship between variables is shown in Table 3.

[3] National Bureau of Statistics of Chin. Retrieved October 20, 2023, from http://www.stat s.gov.cn/english/

Table 2

Basic data on each of the influencing factors in the period from 2000–2014

Years	Economic growth	Industrial structure	Energy consumption structure				Technological progress	Total population	Urbanization rate	Resident life Consumption level	Total energy demand
	GDP / billion yuan	Second production Industry proportion, %	Coal consumption Volume ratio, %	Oil consumption Volume ratio, %	Natural qi dissipates Proportion of fees, %	Primary power, %	Unit GDP Energy consumption	Population	City Conversion rate, %	Residents per capita / yuan	
2000	150 550.8	45.4	68.5	22.0	2.2	7.3	0.976	126 743	36.22	4788.0	146 964.00
2001	163 044.1	44.7	68.0	21.2	2.4	8.4	0.954	127 627	37.66	5980.3	155 547.00
2002	177 866.3	44.3	68.5	21.0	2.3	8.2	0.953	128 453	39.09	5508.5	169 577.00
2003	195 688.4	45.5	70.2	20.1	2.3	7.4	1.007	129 227	40.53	5826.1	197 083.00
2004	215 405.3	45.8	70.2	19.9	2.3	7.6	1.069	129 988	41.76	6243.6	230 281.00
2005	239 859.00	46.9	72.4	17.8	2.4	7.4	1.090	130 756	42.99	6849.5	261 369.00
2006	270 292.8	47.4	72.4	17.5	2.7	7.4	1.060	131 448	44.34	7428.2	286 467.00
2007	308 660.8	46.7	72.5	17.0	3.0	7.5	1.009	132 129	45.89	8375.9	311 442.00
2008	338 364.4	46.8	71.5	16.7	3.4	8.4	0.948	132 802	46.99	9072.1	320 611.00
2009	369 607.4	45.7	71.6	16.4	3.5	8.5	0.909	133 450	48.34	9963.5	336 126.00
2010	408 903.0	46.2	69.2	17.4	4.0	9.4	0.882	134 091	49.95	10 919.0	360 648.00
2011	447 685.4	46.1	70.2	16.8	4.6	8.4	0.865	134 735	51.27	12 124.0	387 043.00
2012	482 382.4	45.0	68.5	17.0	4.8	9.7	0.834	135 404	52.57	13 225.1	402 138.00
2013	519 447.7	43.7	67.4	17.1	5.3	10.2	0.803	136 072	53.70	14 196.2	416 913.00
2014	557 203.9	42.7	66.0	17.1	5.7	11.2	0.765	136 782	54.77	15 308.9	426 000.00

Source: Makeev, Salitski, 2022.

Table 3

Correlation coefficients between variables

	x1	x2	x3	x4	x5	x6	x7	x8	x9	X1
x1	1.0000	−0.3569	−0.3266	−0.7932	0.9812	0.8432	−0.8191	0.9836	0.9892	0.9981
x2	0.3560	1.0000	0.9172	0.2047	−0.4930	−0.7230	0.7003	−0.2287	−0.2487	−0.4068
x3	−0.3266	0.9172	1.0000	−0.2997	−0.4844	−0.7181	−0.7152	−0.1752	−0.2043	−0.3752
x4	−0.7932	−0.2047	−0.2997	1.0000	−0.6741	−0.4284	0.3780	−0.8765	−0.8610	−0.7597
x5	0.9812	−0.4930	−0.4844	−0.6741	1.0000	0.8985	−0.8965	0.9332	0.9448	0.9889
x6	0.8432	−0.7230	−0.7181	−0.4284	0.8985	1.0000	−0.9150	0.7703	0.7827	0.8634
x7	−0.8191	0.7003	0.7152	0.3780	−0.8965	−0.9150	1.0000	−0.7179	−0.7416	−0.8388
x8	0.9836	−0.2287	−0.1752	−0.8765	0.9332	0.7703	−0.7179	1.0000	0.9990	0.9735
x9	0.9892	−0.2487	−0.2043	−0.8610	0.9448	0.7827	−0.7416	0.9990	1.0000	0.9805
x10	0.9981	−0.4068	−0.3752	−0.7597	0.9889	0.8634	−0.8388	0.9735	0.9805	1.0000

Source: compiled by the authors.

As can be seen from Table 2, there is a very strong correlation between annual living expenses and oil consumption. There is a strong correlation between GDP and energy consumption (consumption of primary electricity and other types of energy). Obtained using OLS regression. To the determined coefficient of determination R2 is 0.9997, which indicates a relatively high degree of fit of the model. However, the negative coefficient of the total population does not correspond to reality, since the growth is the total population will necessarily lead to the growth in energy demand, which indicates that there is a problem of multicollinearity between variables (Makeev, 2022).

To build a model for forecasting electricity demand, the PLS method is used in this work.

A standardized regression equation is obtained using regression analysis:

$$Y' = 0{,}155202 + 0{,}0687447\times 2' + 0{,}0757818\times 3' - 0.198451\times 4' + \\ + 0.12798\times 5' + 0.0631958\times 6' - 0.051798885\times 7' + 0.174002\times 8' + \\ + 0.171218\times 9' + 0.147907\times 10' + 3.0386. \quad (1)$$

The PLS regression equation has the form:

$$Y = 011052\times 1 + 5177.21\times 2 + 3655.22\times 3 - 10002\times 4 + 10\,256.6\times 5 + \\ + 5190.39\times 6 - 51\,005.8\times 7 + 5.349\times 8 + 2768.59\times 9 + 4.11142\times 10 - 49\,600. \quad (2)$$

Substituting the data for the corresponding variables from the Table 2 in equation (2), can be calculated to the total energy demand for the period 2000–2014. When compared with actual power consumption, the average error is only 2.325 %, and the standard deviation is 0.020009. Thus, this paper uses an energy demand forecasting model based on the PLS regression method to predict energy demand in China in the future. The energy demand forecasting model based on the PLS regression method has high applicability and reliability (Chang N., 2015).

The projected results are shown in Tables 4 and 5. The total energy demand and the corresponding CO_2 emissions are shown in Tables 4 and 5.

Table 4

Structure of primary energy consumption within the sub-scenario from 2015 to 2022

Years	Benchmark scenario				Constrained scenario			
	coal	petroleum	natural gas	Primary electricity and others	coal	petroleum	natural gas	Primary electricity and others
2015	65.09	17.21	6.05	11.65	64.68	17.24	6.28	11.80
2016	64.17	17.31	6.43	12.09	63.32	17.36	6.91	12.41
2017	63.23	17.40	6.81	12.56	61.92	17.45	7.59	13.04
2018	62.26	17.49	7.21	13.04	60.46	17.53	8.34	13.68
2019	61.28	17.55	7. 64	13.53	58.94	17.58	9. 14	14.34
2020	60. 27	17.62	8.09	14.02	57.40	17.60	10.00	15 00
2021	60.26	17.69	9.01	15.51	56.67	17.62	10.43	15.32
2022	60.24	17.73	9.87	16.02	55.33	17.65	10.56	15.42

Source: compiled by the authors.

Table 5

Structure of primary energy consumption under various scenarios from 2015 to 2022

Years	Baseline scenario		Constrained scenario	
	Total energy demand	CO_2 emissions	Total energy demand	CO_2 emissions
2015	441 186.01	944 447.95	437 712.97	932 419.26
2016	456 563.92	969 041.04	450 014.88	946 169.60
2017	473 182/38	996 029.06	463 979.78	963 540.47
2018	491 115.90	1025 545.98	479 711.18	984 726.40
2019	510 444.30	1057 739.25	497 321.89	1009 959.63
2020	531 253.14	1092 771.10	516 934.79	1039 515.42
2021	558 975.54	1098 713.34	527 513.81	1041 231.11
2022	567 632.12	1126 571.42	533 241.01	1051 871.63

Source: compiled by the authors on the basis of Akhmetov V.R., Smirnov O.V. (Akhmetov, Smirnov, 2020)

Next, let's look at the aspect of energy's consumption structure. Under this bacground transition to low-carbon development, taking into account energy, economic and environmental factors, a multi-purpose optimization model of the structure of energy consumption is constructed in this paper.

Discussion

The hypothesis of this work is that in the conditions of transition to low-carbon development, the goal of the model is to ensure the growth of China's economy at an average high rate with the lowest total energy consumption and the lowest CO_2 emissions.

For primary electricity and other energy sources, only hydropower, nuclear power and wind power are considered, and hydropower, nuclear power and wind power have been developing in parallel since 2010, the cost of energy use and the cost of CO_2 recovery remain unchanged compared to 2010, China's GDP in the period 2015–2022 is growing by 7 %.[4]

The basic and optimized scenario of the energy consumption structure for 2015–2022 is presented in Figure 1.

Compared to the baseline scenario, energy consumption in China in 2022 with an optimized energy consumption structure will be reduced by 36,783.14 million tons of standard coal, which is about 6.92 % of the baseline scenario. At the same time, the growth rate of the energy saving potential in the period 2015–2020 is gradually increasing — about 6.92 % of the baseline scenario.

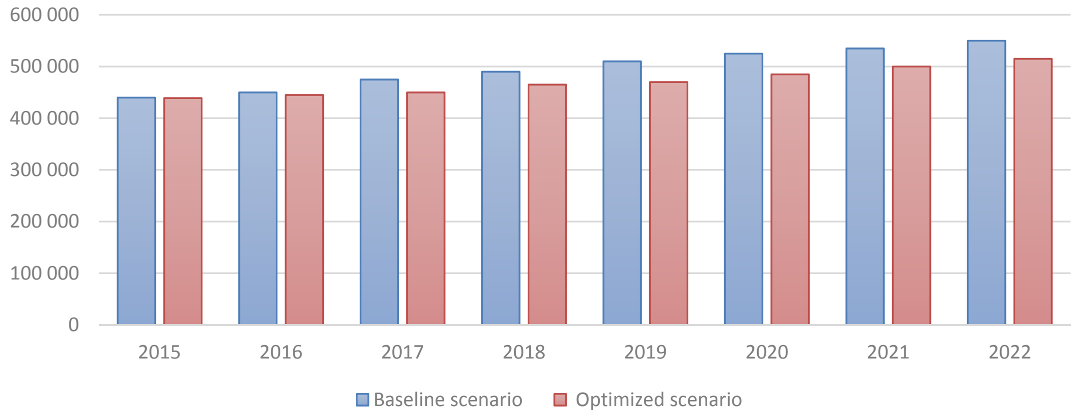

Figure 1. Baseline scenario and optimized scenario of energy consumption structure in China, 2015–2022
Source: compiled by the authors.

The energy saving potential in 2015 is 1.01 %, and the energy saving potential in 2016 is 1.01 % higher than in 2015. The energy saving potential in 2016 is 0.93 % higher than in 2015. The growth rate of the energy saving potential is accelerating

[4] China Energy Program. International Energy Analysis. Retrieved October 20, 2023, from https://china.lbl.gov/sites/default/files/misc/ce d-9-2017-final.pdf

significantly over time, and by 2020 the energy saving potential is 1.42 percentage points higher than in 2019. One of the important reasons is that the period of China's the thirteenth Plan with 5 years is a transitional period for China's low-carbon development. The share of sustainable energy sources with high calorific value will increase as a result of technological progress in the field of energy use, which will lead to a significant reduction in total energy consumption. Overall energy consumption has decreased significantly as a result of technological advances in energy use.

According to the scene of optimizing the structure of energy consumption, the structure of energy consumption in China will change significantly. In particular, in 2015–2022, coal accounted for a significant share of China's total energy consumption. The share of coal consumption is sharply decreasing — from 65.29 % in 2015 to 60.64 % in 2020, that is, by 4 %, the share of oil consumption decreases from 16.59 % in 2015 to 14.00 % in 2020, a decrease of 2.0 %. The share of natural gas, primary electricity and other clean energy sources increased significantly from 6.32 % in 2015 to 14.00 % in 2020, a decrease of 2.59 %. Compared to the baseline scenario, the share of natural gas, primary electricity and other clean energy sources increases by 3.25 %.

The potential for reducing CO_2 emissions in China in 2015–2020. According to the scene of optimizing the structure of energy consumption is shown in Figure 2. With the gradual optimization of the energy consumption structure, the reduction of CO_2 emissions achieves obvious results.

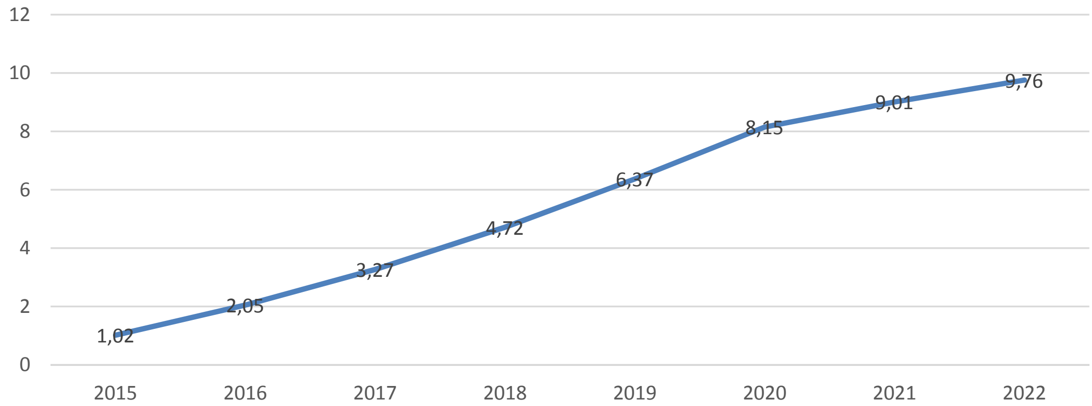

Figure 2. Scenario for optimizing the energy consumption structure from 2015 to 2020. China's potential to reduce CO_2 emissions

Source: compiled by the authors.

In 2015, the potential for reducing CO_2 emissions is 1.02 %, and by 2020–8.15 %, which is an obvious effect of reducing CO_2 emissions. Just like the energy saving potential, the growth rate of the CO_2 reduction potential is gradually accelerating. As well as the potential for energy saving, the overall growth rate of the potential for reducing CO_2 emissions is accelerating, and the potential for reducing CO_2 emissions in 2016 is 1.03 percentage points higher than in 2015, and the potential for reduction in 2020 is 1.65 percentage points higher than in 2019.

One of the important reasons is that the period of the “China’s the thirteenth Plan with 5 years” is a transitional period of low-carbon development in China, characterized by a reduction in coal consumption and an increase in the share of clean energy consumption.

Reducing coal consumption and increasing the share of clean energy consumption will lead to a significant reduction in CO_2 emissions.

Conclusion

Thus, in the article, the PLS regression method is used to build a model for forecasting energy demand, and scenario modeling is used to predict total energy demand, energy consumption patterns and CO_2 emissions. The total energy demand, energy consumption structure and CO_2 emissions in China during China’s the thirteenth Plan with 5 years are predicted using scenario modeling and a multipurpose optimization model of the energy consumption structure is built, taking into account the features of the new normal economy. Results by this research as follows:

Firstly, the pressure on energy conservation and emissions reduction in China during China’s the thirteenth Plan with 5 years will be stronger. The total energy demand in China in 2020, according to the baseline scenario, will amount to 531,253.14 million tons of standard coal, and CO_2 emissions — 1,092,271.1 million tons.

Secondly, optimizing the energy consumption structure can effectively reduce overall energy consumption and CO_2 emissions. By 2020, the total energy consumption in China with an optimized energy consumption structure according to the scenario, China consumed energy equivalent to 4,944.7 million tons of standard coal that year, and the corresponding CO_2 emissions will be 1,33258.25 million tons. Compared to the baseline scenario, by 2020 the total energy consumption in China will be compared with the baseline scenario, by 2020, revise China’s energy consumption structure, shown down 347.086 million tons of standard coal in use, reduce carbon dioxide emissions by 347.086 million tons (about 6.55 % of the baseline scenario), and energy consumption with an optimized energy consumption structure will decrease by 2020.

Finally, optimization of the energy consumption structure can ensure the transition to low-carbon development. By 2023, according to the scenario of optimizing the structure of energy consumption, the share of coal (60.63 %), oil (14 %), natural gas (14 %), primary electricity (14 %) and other energy carriers in primary energy consumption will be 14 %, respectively.

The share of coal, oil, natural gas, primary electricity and other energy carriers in primary energy consumption under the optimized scenario of the energy consumption structure will be 60.63, 14.00, 10.36, 15.00 %, respectively.

Compared to the baseline scenario, natural gas, primary electricity and other clean energy account for 60.63 % of primary energy consumption. Compared to the baseline scenario, the total share of consumption of natural gas, primary electricity and other clean energy sources increases by 3.25 %.

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