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Environmental Pollution of Chinese Industrial Enterprises and Energy Conservation, and Emission Reduction Environmental Protection Strategies from the Cyclic Economy Perspective

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ABSTRACT

High emission, pollution, and energy consumption problems that result from rapid economic development have not yet been effectively solved. As an important force that drives economic development, industrial enterprises have caused considerable environmental pollution. To analyse the current status and causes of environmental pollution generated by Chinese industrial enterprises and propose concrete energy conservation and emission reduction environmental protection measures, this paper first reviewed Chinese and foreign studies on strategies that addressed environmental pollution caused by industrial enterprises. Then, the environmental pollution status of industrial enterprises was analysed, and problems in energy conservation and emission reduction of industrial enterprises, and their causes were identified. Finally, energy conservation and emission reduction strategies for industrial enterprises were proposed. Results indicate that environmental pollution of industrial enterprises is reflected through a rapidly growing proportion of total energy consumed by industrial enterprises, large industrial "three wastes" emission load, and year-by-year decline of the elasticity coefficient of energy consumption. The problems in energy conservation and emission reduction of industrial enterprises are an unreasonable industrial structure; a distinct contradiction in energy consumption structure; difficulty in guaranteeing various inputs of energy conservation and emission reduction; imperfect energy conservation and emission reduction policies and regulations; and insufficient marketing measures. The main cause of the environmental pollution generated by industrial enterprises is the lack of effective supervision for the implementation of energy conservation and emission reduction policies, and low awareness about energy consumption and emission reduction. Our findings are critical to further understanding the environmental pollution caused by industrial enterprises, encouraging the government to formulate energy conservation and emission reduction measures in accordance with the practical situation, and enabling industrial enterprises to continuously reduce their energy consumption and emission.

INTRODUCTION

The economic development process in China only highlights growth speed and neglects growth quality, thereby resulting in excessive emission and energy consumption. As a result, environmental pollution in China has worsened and is accompanied by excessive energy consumption. China should adopt clean and sustainable economic development unlike European and American countries, which wasted energy sources during their modernization process, thereby posing great harm to the environment and resulting in declining environmental carrying capacity. Severe global ecological pollution is the best evidence of this problem. Thus, energy conservation and emission reduction are of profound significance to whether the transformation of the economic development pattern of China can succeed.

The Chinese industrial economy is developing swiftly at present (Fig. 1), and the harmful effects of excessive resource consumption and waste discharge have already been observed. In recent years, both total energy consumed and total industrial energy consumed have increased year by year with the frequent occurrence of environmental and resource problems, thereby seriously limiting the healthy economic development of the nation. Severe challenges posed by resource pressure and environmental carrying capacity to Chinese economic development surpass those faced by developed European and American countries during their industrialization process. Energy conservation and emission reduction should specifically include the control of energy waste and reduction of waste discharge. The main objective of enterprises is to seek profit for production and management to produce diversified products and provide services needed by people. To realize the above objectives, enterprises have to consume large amounts of energy sources and emit waste into the environment during the production process. Energy conservation and emission reduction of

industrial enterprises refer to sufficient adjustment of the energy structure through energy conservation to achieve a reasonable structure and reduce energy usage behaviour (production and operation activities).

Therefore, the active promotion of energy conservation and emission reduction of industrial enterprises is an urgent strategic task that should be completed within a certain time in the future. Energy conservation and emission reduction of industrial enterprises is a systematic project that requires the resultant force of multiple fields. The government, which has a dominant role in this endeavour, should maximize its executive functions, actively guide the energy conservation and emission reduction activities of industrial enterprises, force industrial enterprises to implement energy consumption and emission reduction policies, and facilitate the continuous expansion of the influencing force of policies. Moreover, the government should further promote the establishment of harmonious relationships of economic construction with resources and the ecological environment, as well as vigorously facilitate energy conservation and emission reduction to contribute to the rapid, positive development of the economy and the environment.

STATE OF THE ART

Energy sources and resources are scarce, and resource and energy consumption has typical externality features. Energy conservation and emission reduction have emerged as a means of solving this problem. Foreign studies on energy conservation and emission reduction policies largely combine taxation and enterprises' energy conservation and emission reduction efforts (DeCanio 1993) introduced externality and public finance theories, and found that energy products have extremely high externality. The suggested approach was for relevant government departments to formulate relevant preferential policies that are beneficial for individuals to encourage them to invest in energy conservation and emission reduction products. Freeman et al. (1997) used the data envelopment analysis (DEA) to discuss early measurement of energy efficiency. Drezner (1999) analysed the effects of the energy conservation and emission reduction policies of some developed countries and found that these policies had a favourable effect. He also believed that taxation would become the general trend of future energy conservation and emission reduction policies. From an empirical perspective of Switzerland environmental taxation policies, Miranda et al. (2002) verified that environmental taxation policies could encourage consumers to actively participate in energy conservation and emission reduction, and ultimately reduce the energy conservation and emission of Switzerland. Liu et al. (2002) conducted an energy industry analysis and suggested that the government focus on supporting power generation projects through renewable energy sources like wind power and solar energy. Babiker (2005) believed that enhancing low-carbon technological innovation and upgrading, emphasizing the development and utilization of renewable energy sources, and formulating government policies to perfect the marketing system could reduce carbon emission and achieve environmental protection. Wiesenthal et al. (2009) studied the influences of energy taxes on prices of all kinds of energy sources and believed that the government should formulate a series of policies and regulations or guide enterprises to improve their energy conservation and emission reduction through administrative means, such as setting industrial standards. Song et al. (2013) used DEA to analyse the relationship between energy efficiency and carbon emission of Brazil, Russia, India, and China, and found that this relationship changes the energy structure. Hasanbeigi et al. (2013) selected Chinese iron and steel enterprises as study objects to analyse their energy conservation and emission reduction status, and determine their energy conservation and emission reduction potential. Li et al. (2016) used three-phase DEA model to analyse the influence of energy protection policies on green productivity in the manufacturing industry of China. Zhou et al. (2016) used non-parametric analysis to study the performance of Chinese industrial enterprises in energy conservation and emission reduction. Yuan et al. (2016) analysed the policy effects on energy conservation and emission reduction in the electric power industry of China. Chen et al. (2017) analysed the cost and potential of energy conservation and emission reduction in the coal-fired power generation industry of China. By using Jing-Jin-Ji region in China as an example, Du et al. (2017) analysed the energy conservation and emission reduction paths of road traffic up to 2030. Guo et al. (2017) evaluated the regional energy conservation and emission reduction efficiency on the basis of the improved slow-down measurement method. Existing Chinese and foreign studies mainly concentrate on the effects of energy conservation and emission reduction on the environment and the economy, as well as mutual relationships among the three. They separately observed the effects of one or some policies or the implementation of energy conservation and emission reduction in one industry, as well as next-step countermeasures and plans. Although various provinces and cities have paid slightly more attention to energy conservation and emission reduction and the formulation of policies from a qualitative angle in recent years, quantitative research is still minimal. Few studies focus on the implementation effects of government policies on energy conservation and emission reduction for industrial enterprises from the cyclic economy perspective. Through a

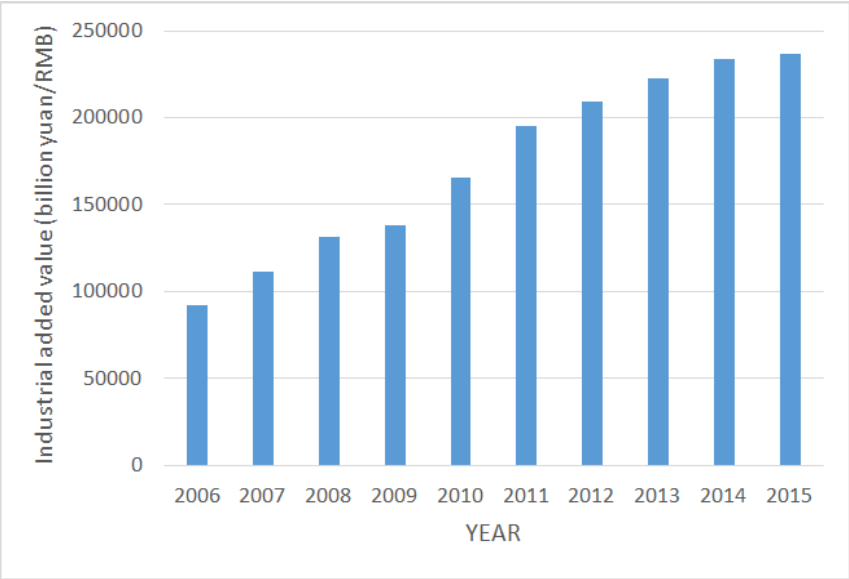

Fig. 1: Industrial added values in China during 2006-2015.

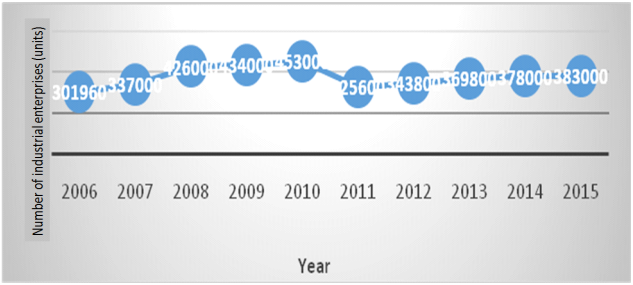

Fig. 2: Number of industrial enterprises in China during 2006-2015.

review of the in-depth implementation and utilization of government energy conservation and emission reduction policies by industrial enterprises, this paper emphasizes the importance of government-guided energy conservation and emission reduction work of industrial enterprises from the cyclic economy perspective. This paper expects to provide reference suggestions for energy conservation of industrial enterprises and improvement of energy conservation and emission reduction policies of the government.

ENVIRONMENTAL POLLUTION STATUS OF INDUSTRIAL ENTERPRISES

During the 12th Five-year Plan, China emphasizes the strengthening of sustainable development, adjusting the proportion of energy consumption in the industrial economy, and shifting the way of thinking in this field. During the industrial development process, China vigorously promotes the industrial structure optimization, eliminates backward productivity, and actively develops the cyclic economy. Significant results have been achieved in energy conservation and cost reduction. However, industrial enterprises have been increasing continuously, as shown in Fig. 2. China has been actively boosting industrial energy conservation and cost reduction, and comprehensive energy-consuming industries have been declining continuously, thereby significantly improving energy utilization efficiency. The main energy consumption indexes, all exhibit a decreasing trend.

Increasing growth of the proportion of total energy consumed by industrial enterprises: Given the primary proportion of heavy-chemical companies in the industrial structure, controlling the total energy consumed is difficult. As can be seen from Fig.3, the development speed of the heavy industry might still be higher than that of the light industry in 2015. However, the heavy-chemical trend of the industrial structure means that the proportion of industrial energy consumption remains high, and controlling the total energy consumed in the industrial field is difficult. The total energy consumed in China grows slowly, energy consumption structure tends to be more stable, and the proportion of clean energy sources continues to rise.

Large industrial "three wastes" emission: The industrial engineering has developed rapidly in recent years, and its total output value has increased dramatically at the same time. Irresponsible discharge of waste generated during industrial production and growing energy consumption negatively affect the regional ecology and sustainable energy

utilization. The negative effects of waste production are mainly manifested by excessive emission of the industrial "three wastes." Atmospheric pollutants mainly include soot, dust, and sulphur dioxide, and water pollutants are mainly chemical oxygen demand and ammonia nitrogen. The polluting elements of solid wastes take a long time to break down and have far-reaching effects on the surrounding environment through water, atmosphere and soil.

Year-by-year decline of elasticity coefficient of energy consumption: The elasticity coefficient of energy consumption is the index of the relationship between the economy and the growth rate of energy consumption, and it can be calculated according to the ratio of these two factors. Its variation is closely related to energy utilization efficiency, proportion of economic structure, technical equipment level, development of production technology and management level. Fig. 4 shows the declining trend of this index during the 12th Five-year Plan, thereby indicating that the growth rate of energy consumption is lower than that of the gross domestic product. Through the promotion of industrial energy-saving technology and the adjustment of the economic structure, awareness about industrial energy resources is continuously enhanced. Multiple measures are actively taken to improve utilization efficiency, and the energy conservation and emission reduction work of industrial enterprises have achieved evident results.

PROBLEMS IN ENERGY CONSERVATION AND EMISSION REDUCTION OF INDUSTRIAL ENTERPRISES

Unreasonable industrial structure: The unreasonable characteristics of the industrial structure has increasingly been observed. The traditional heavy industry has not undergone timely upgrades because of limiting factors, such as slow-transition capital. The emerging industrial development is insufficient, which cannot be compared with the situation of other provinces. Fundamental urban functional construction is developing slowly and cannot provide superior services for industrial upgrades. The clustering effect of the economic development of the heavy industry is weak, and ensuring that it can help improve other industries is difficult. Moreover, economic development still centres on simple resource development, processing, and output. Industrial development lacks planning, and the industrial independence of various enterprises is strong yet has a weak cooperative development effect.

Distinct contradiction in the energy consumption structure: Industries that are overdependent on resources practice coyoting and deforestation, and the ecological regime within the scope of jurisdiction is continuously degraded. The weak renewability and long-term requirements of resources mean that resource reserves are exhausted. New-energy industries have not been sufficiently cultivated or incubated. Therefore, sustainable development of the energy industry is at risk. In addition, resource-intensive industries have high energy consumption and pollution. With excessive energy exploitation, a large amount of energy sources are wasted. Reckless exploitation is needed to promote economic development; this action forms a vicious cycle and continuously harms the overloaded ecological environment.

Inability to guarantee the long-term various inputs of energy conservation and emission reduction: To create an energy conservation and emission reduction plan, China is actively taking measures to remove and transfer enterprises with serious pollution and high energy consumption or force them to shutdown for regulation. Although these measures promote energy conservation and emission reduction to some degree, some enterprises belong to industries with a high industrial output value. These administrative means have harmed economic initiative to a certain extent, and a gap still exists with the goal of a harmonious relationship between Chinese economic development and energy conservation and emission reduction.

PROBLEMS IN ENERGY CONSERVATION AND EMISSION REDUCTION OF INDUSTRIAL ENTERPRISES

Imperfect energy conservation and emission reduction policies and regulations: High input, high energy consumption, and high emission have been problems in economic development for a long time, and economic development has posed enormous harm to the sustainability of ecology and resources. With the lack of a powerful legal restraint mechanism and comprehensive legal protection related to energy conservation and emission reduction, the cost of ecological and resource destruction is low. Thus, comprehensive constraints in energy conservation and emission reduction are lacking. Existing law clauses are not strongly feasible and are insufficiently combined with practical activities in industrial production. Recapitulative expression is all that is available in this case. As a result, defining relevant standards, methods, and paths in the execution process is difficult for industrial enterprises. The government lacks powerful resource recycling measures. Thus, a highly efficient incentive mechanism for energy conservation and emission reduction for enterprises is difficult to formulate. Moreover, the illegal actions of enterprises are not punished severely enough, and any action has a weak restriction effect. Therefore, energy conservation and emission reduction is relatively weak during the promotion process.

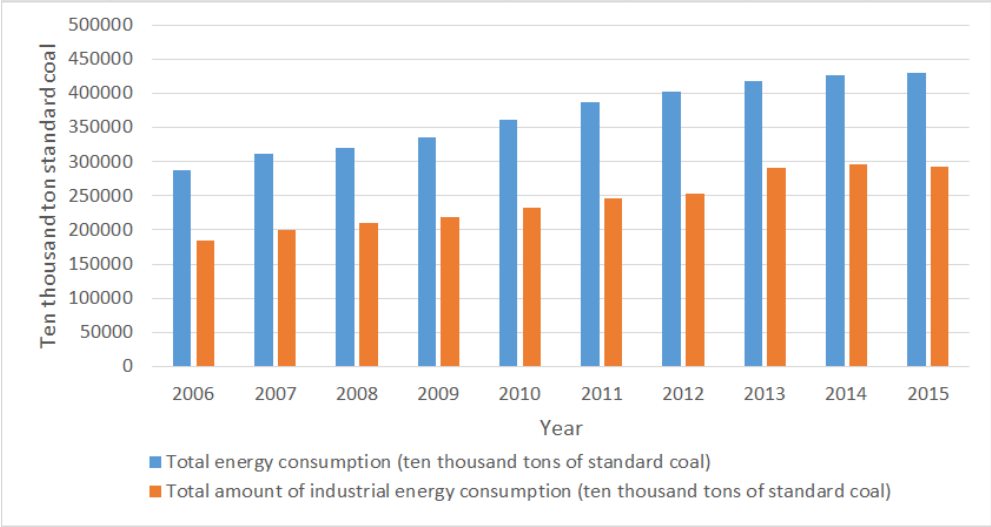

Fig. 3: Comparison of energy consumption and total industrial energy consumed during 2006-2015.

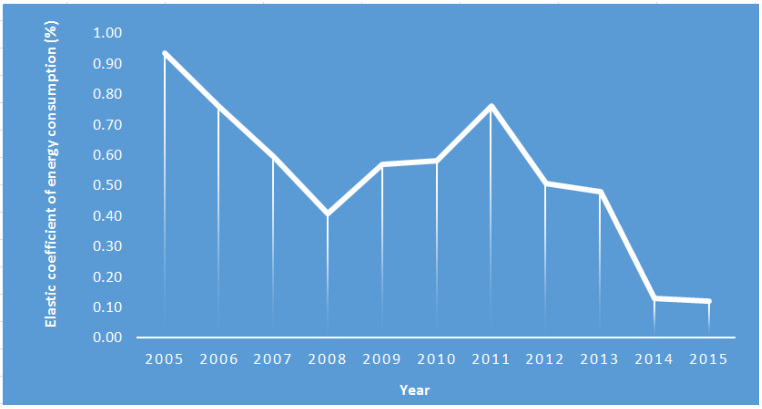

Fig. 4: Elasticity coefficient of energy consumption during 2005-2015.

Insufficient marketing measures: Marketing measures such as the provision of funds, guidance for price execution, and taxation should be taken to apply a marketing influence on energy conservation and emission reduction. The availability of a large amount of government funds is a powerful measure to guide the implementation of energy conservation and emission reduction. However, the relative deficiency of government funds result in an insufficient specialized input fund for new-energy industries. An effective means of energy conservation and emission reduction is to ensure that the prices of industrial products comprehensively reflect the energy conservation and emission reduction costs. Continuous shortage of resources and the cost of environmental disruption should be presented in a timely manner. However, an effective guidance mechanism that embodies energy conservation and emission reduction cost of industrial products is lacking. The taxation mode of promoting energy conservation and emission reduction of enterprises lacks flexibility, and it is only represented by relatively stiff value-added and consumption taxes. The administrative function of relevant taxation is strong. However, the guiding effect of taxation on energy conservation and emission reduction has not been fully revealed.

Lack of effective supervision for energy conservation and emission reduction policies: Environmental protection departments lack executive authority, legal protection, and implementing power. Thus, punishing those who violate laws and regulations is difficult. Effective control of the behaviour of individual units is difficult, and as a result, the regulatory agency is unable to achieve its desired deserving effects. Therefore, supervisory and administrative departments should be granted the authority to implement

energy conservation and emission reduction policies and regulations. Stipulations of laws and regulations should be refined to enhance executability, strengthen the evaluation of supervision and administration of energy conservation and emission reduction, and define the relationship between the rights and the obligations of the government, executive agency, and executing unit. No effective regulation of gambling relations among the nation, local government, and enterprises in execution of energy conservation and emission reduction policies.

Weak awareness about energy conservation and emission reduction: The understanding of some industrial enterprises that have high energy consumption and high emission has not been updated. They place insufficient emphasis on energy conservation and emission reduction. Moreover, they are not equipped with specialized resources for energy conservation and emission reduction, and they have inadequate understanding of the cost effectiveness of energy conservation and emission reduction, as well as lack interest in executing related tasks. Some enterprises have a backward cost management concept. Product costs reflect only the costs of input raw materials, manual work, and depreciation of machinery equipment, and do not consider energy and pollutant discharge costs. As a result, the prices of energy sources and other industrial products are low. Some local governments focus mainly on performance and emphasize only the enterprises with high energy consumption and large emissions. No detailed study has been conducted on the energy conservation and emission reduction capacity of companies in other industries; thus, these companies have not been the subject of sufficient attention. In addition, the government mainly seeks to meet economic indexes while neglecting energy conservation and control of pollutant discharge during the economic development process.

ENERGY CONSERVATION AND EMISSION REDUCTION STRATEGIES OF INDUSTRIAL ENTERPRISES

Controlling the excessively rapid growth of "two high" (high energy consumption and high emission) industries and promoting the transformation and upgrading of traditional industries: Given the traditional resource advantages of China, the development and utilization of petrochemical resources have been accompanied with high energy consumption and emissions. To promote energy conservation and emission reduction, the exploitation and utilization of petrochemical resources should be considered first, and then energy consumption and emission indexes of petrochemical resources, including petroleum and coal, should be strictly formulated. Diversified measures, including supervision and monitoring measures, should be taken. Energy consumption and emission standards in the two industries should be established through laws and regulations. The monitoring of the execution process and relevant results should be conducted in a sustainable manner. The government should elevate industry access standards, ensure a strict approval process for relevant projects, promote industrial mergers, form large-scale and high-technical-content enterprises to develop and utilize energy sources, increase the utilization and assembly proportion of cleaner production equipment, and accelerate the shutdown of small workshop-style energy development enterprises. Optimization and improvement of traditional industrial structure are the key to energy conservation and emission reduction, and they play a crucial role in whether the goal can be realized and can serve as a powerful engine for economic development. The government should combine the actual situation of economic development and energy conservation and emission reduction to comprehensively plan the development of industrial enterprises; guide enterprises in upgrading their equipment; reform processing technologies; conduct research and development of new products, and increase the contribution of enterprises to energy conservation and emission reduction. The government should actively develop and motivate industries with low energy consumption and strong awareness of environmental protection. Industries like petrochemical engineering and energy processing, which have high energy consumption and heavy pollution, should be encouraged by the government to adopt scaled production, exert their scale effect, elevate their processing level, and increase the proportion of products with low energy consumption and high environmental protection.

Continuously to perfect the assessment and evaluation system of energy conservation and emission reduction and establish a laws and regulations system for energy conservation and emission reduction: Most attention is paid to profit and benefit indexes during the development process of industrial enterprises, whereas less concern is given to the environment and resource sustainability. Not enough importance is attached to the development pattern of high energy consumption and high emission of enterprises, thereby resulting in wasted energy sources and the discharge of a large amount of wastes into the environment. The government should set an assessment and evaluation system for energy conservation and emission reduction to ensure that violations of enterprises can be pinpointed in time and effectively quantified; reasonable measures will be taken according to quantitative indexes. Setting quantitative indexes can facilitate the comprehensive mastery of energy conservation and emission reduction of industrial enterprises, thereby contributing further to the evaluation

of the effects of government energy conservation and emission reduction policies. The government should define the legal ground for industrial enterprises to execute energy conservation and emission reduction policies and continuously incorporate energy conservation and emission reduction work into legislative framework. This approach ensures that laws exist by which government energy conservation and emission reduction efforts, enterprise behaviours, and social institution can abide. Legislation on energy conservation and emission reduction should concentrate on the operability and comprehensiveness of articles of laws. Legislative contents should include energy conservation and utilization, governance of industrial waste discharge, and development of clean energy sources. Moreover, the government should standardize the entire process from energy acquisition, processing and utilization, and waste discharge. To ensure a collaborative effect, such a system of standards should be complete and form an integrated system with relevant environmental protection laws. Gambling relations among the nation, local government, and enterprises in the execution of energy conservation and emission reduction should be effectively regulated.

Encouraging the development and acceleration of the industrialization of energy conservation and emission reduction technology: The government should value the utilization efficiency of biological and solar energy sources, actively conduct talent technical exchange and learning, vigorously promote new energy technological development through scientific research in universities and enterprises, and facilitate technological industrialization and utilization as soon as possible. Enterprises should actively develop recycling technologies and reduce energy consumption and pollutant discharge. During the energy source development and utilization process, a comprehensive understanding and cognition should be developed with regard to the entire energy utilization process, various utilization indexes, and consequences. Automation of energy measurement and control is particularly important at present. Given the present scientific and technological situation, we need to take full advantage of computer and process simulation technologies and of the internet cloud technology for data analysis. The government should strengthen the utilization of available advanced technology and methods to implement key engineering construction and drive the progress of industrial energy conservation with the demonstrative effect of advanced enterprises. With technologies such as desulphurization, denitrification, and industrial waste disposal as the core, enterprises should actively seek technological breakthroughs and continuously promote the industrialization of energy conservation and emission reduction technologies. Relevant industrial parks should be rapidly constructed. The government should form a system outline, formulate key technological means of energy conservation suitable for provincial situations, and establish talent selection and application systems. Stepwise application and recycling of energy sources should be realized (mainly electrical application), and the application of mature scientific and technological methods such as thermal energy conversion and the application of relevant equipment and technology should be accelerated. Enterprises should strengthen cooperative relationships, improve communication efficiency and quality, innovate their cooperative modes, increase "going out" speed, and introduce, learn, utilize, and innovate Chinese and foreign excellent energy conservation and emission reduction methods by all means.

Emphasizing scientific and technological innovation and improving the technological innovation ability of enterprises: The government should take full advantage of highly efficient scientific research; highlight the achievements of people in scientific research and development; actively guide and encourage innovative salary incentives such as stock options; make every effort to give policy and tax incentives; and establish a scientific manpower training system suitable for the current situation of energy conservation and emission reduction. Enterprises are a key factor in energy conservation and emission reduction, and they primarily drive scientific research on energy conservation and emission reduction. The government should actively guide scientific research on energy conservation and emission reduction of industrial enterprises, and ensure that enterprises continuously improve their scientific research abilities on the subject, as well as innovate their management concepts and enhance the internal sustainability of their energy conservation and emission reduction work. From the technical aspect, the government should provide scientific research funds for enterprises, allocating a fixed sum for a fixed purpose; provide subsidy or tax preference for relevant expenditures; and ensure the timely distribution of the full amount of technological research funds for energy conservation and emission reduction. The government should emphasize the functional exertion of the market during the promotion process of scientific and technological innovation while highlighting the dominant roles of enterprises as innovators. The government should facilitate the establishment of university-enterprise innovation platform, pay attention to intellectual property protection of scientific research, and build an effective channel between scientific research in universities and commercialized application. Enterprises should emphasize the roles of people, optimize resource allocation, change extensive management patterns, refine the division

mechanism of responsibilities, apply advanced assessment and evaluation means and equipment for emission reduction, and guide and support policies on scientific research on energy conservation and emission reduction.

CONCLUSION

As an important force of socioeconomic development, industrial enterprises have caused considerable environmental pollution while promoting economic development. To analyse the status and causes of environmental pollution generated by Chinese industrial enterprises and present concrete energy conservation and emission reduction environmental protection measures, this paper analysed the environmental pollution status of industrial enterprises and identified the problems in the energy conservation and emission reduction efforts of industrial enterprises and their causes. Findings show a high proportion of total energy consumed by industrial enterprises and industrial "three wastes" discharge. The elasticity coefficient of energy consumption decreases year by year, thereby indicating that energy conservation and emission reduction measures have relieved environmental pollution. Environmental pollution of industrial enterprises is caused by four factors: imperfect energy conservation and emission reduction policies and regulations, inadequate marketing measures, lack of effective supervision for the execution of energy conservation and emission reduction policies, and low awareness about energy conservation and emission reduction. Energy conservation and emission reduction can be realized by inhibiting the excessively rapid growth of "two high" (high energy consumption and high emission) industries, continuously perfecting an assessment and evaluation system for energy conservation and emission reduction, encouraging the development of energy conservation and emission reduction technology, and emphasizing scientific and technological innovation. Future in-depth studies can focus on the following subjects: energy conservation and emission reduction efficiency of industrial enterprises; effect of an internal functioning mechanism of the cyclic economy on the environmental governance of industrial enterprises; internal dynamic mechanism of the environmental protection of industrial enterprises; and the existence of regional differences in energy conservation and emission reduction between different scales of industrial enterprises.

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REFERENCES

Babiker, M.H. 2005. Climate change policy, market structure, and carbon leakage. Journal of International Economics, 65(2): 421-445.

Chen, H., Kang, J.N. and Liao, H. et al. 2017. Costs and potentials of energy conservation in China's coal-fired power industry: A bottom-up approach considering price uncertainties. Energy Policy, 104: 23-32.

DeCanio, S.J. 1993. Barriers within firms to energy-efficient investments. Energy Policy, 21(9): 906-914.

Drezner, J.A. 1999. Designing effective incentives for energy conservation in the public sector. Dissertation Abstracts International, 60-02: 242.

Du, H., Liu, D. and Southworth, F. et al. 2017. Pathways for energy conservation and emissions mitigation in road transport up to 2030: A case study of the Jing-Jin-Ji area, China. Journal of Cleaner Production, 162: 882-893.

Freeman, S.L., Niefer, M.J. and Roop, J.M. 1997. Measuring industrial energy intensity: practical issues and problems. Energy Policy, 25(7-9): 703-714.

Guo, X., Zhu, Q. and Lv, L. et al. 2017. Efficiency evaluation of regional energy saving and emission reduction in China: A modified slacks-based measure approach. Journal of Cleaner Production, 140: 1313-1321.

Hasanbeigi, A., Morrow, W. and Sathaye, J. et al. 2013. A bottom-up model to estimate the energy efficiency improvement and CO_2 emission reduction potentials in the Chinese iron and steel industry. Energy, 50: 315-325.

Li, K. and Lin, B. 2016. Impact of energy conservation policies on the green productivity in China's manufacturing sector: Evidence from a three-stage DEA model. Applied Energy, 168: 351-363.

Liu, W.Q., Gan, L. and Zhang, X.L. 2002. Cost-competitive incentives for wind energy development in China: Institutional dynamics and policy changes. Energy Policy, 30(9): 753-765.

Miranda, M.L. and Hale, B.W. 2002. A taxing environment: Evaluating the multiple objectives of environmental taxes. Environmental Science & Technology, 36(24): 5289-95.

Song, M.L., Zhang, L.L. and Liu, W. et al. 2013. Bootstrap-DEA analysis of BRICS'energy efficiency based on small sample data. Applied Energy, 112: 1049-1055.

Wiesenthal, T., Leduc, G. and Christidis, P. et al. 2009. Biofuel support policies in Europe: Lessons learnt for the long way ahead. Renewable and Sustainable Energy Reviews, 13(4): 789-800.

Yuan, J., Na, C. and Hu, Z. et al. 2016. Energy conservation and emissions reduction in China's power sector: Alternative scenarios up to 2020. Energies, 9(4): 266.

Zhou, D.Q., Wang, Q. and Su, B. et al. 2016. Industrial energy conservation and emission reduction performance in China: A city-level nonparametric analysis. Applied Energy, 166: 201-209.