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Comparison and Analysis on Energy Governance Models of Global Major Powers

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Abstract. Currently, the world is facing major changes that have not occurred in a century, and global energy governance has undergone significant new changes. The energy development trends of global major powers were clarified in the Paper by studying and judging the changes in the global energy consumption structure. The performance evaluation index system for major powers on their participation in global energy governance was constructed, so that the comprehensive comparison and analysis was conducted for the participation of eight countries, including China, the United States, Japan, the United Kingdom, Germany, France, Russia, and India, in global energy governance from four dimensions of economic, technological, social, and political. Generally, the United States has the highest overall performance score in participating in global energy governance, followed by China, the United Kingdom, France, Germany, and Japan, with Russia and India in the third and fourth echelons respectively. The cooperation with major economies on green governance can be strengthened by China under the framework of the United Nations, the G20 and "the Belt and Road Initiative", and a global climate governance pattern of joint consultation, construction and sharing will form, so as to maximize the effect of global climate governance.

Keywords: Energy governance model; Energy governance evaluation method.

1. Introduction

Currently, global governance has entered a transition period, and the original global governance structure led by western developed countries has made the deficiencies that cannot be changed prominent when it was used to deal with non-traditional security issues such as climate change. Furthermore, China and other emerging powers have continuously strengthened their own strength in global affairs, and it is urgently need to be change the global governance system. Michael T. Klare believes that the economic impact of the COVID-19 epidemic is likely to be a huge change in the sustainable use pattern that will accelerate the departure of fossil fuels such as oil from the center of the world energy structure, and renewable energy, nuclear power, oil, natural gas and coal will form a coexistence and diversification pattern. Currently, the trend towards achieving multiple goals of energy governance through new energy and new paths is strengthened: First, the primary goal of energy governance is to prevent extreme fluctuations in prices and supply. Secondly, the realization of the goal of "energy governance and poverty eradication" requires market orientation and universal development. Sustainable solutions to energy issues need to address both the demand and supply aspects of the energy system, which requires market intervention and intent signals of governments. Finally, energy governance under climate change is moving towards a market-oriented development path. As one of the most prominent global issues, climate change markers should adhere to people-oriented diplomacy, rather than simply material consumption and wealth consolidation. In the face of new changes in the global energy governance environment, global energy governance construction faces a new window of opportunity. It is necessary to clarify the evaluation system of major powers competition from the perspective of global energy governance, define the geopolitical, political, military, economic, and financial games among various entities on energy, as well as the coordination in the fields of resource technology, sustainable utilization and distribution of resources, and price stability, so as to formulate reasonable and efficient energy policies from a multi-dimensional perspective for maintaining China's energy security.

2. Energy development trends of global major powers

Generally, there have been significant changes in the global energy system structure from 2017 to 2020. On the one hand, energy consumption in major countries and regions around the world is still on the rise, which indicates that global economic development still requires a large amount of energy as support; on the other hand, the consumption of renewable energy is gradually increasing in the energy consumption structure of major countries and regions around the world.

Table 1. Energy Consumption of Major Countries and Regions in the World from 2017 to 2020 Data source

	Primary energy consumption (EJ) from 2017 to 2020				Carbon emissions (million tons) from 2017 to 2020			
	2017	2018	2019	2020	2017	2018	2019	2020
the United States	92.33	95.60	94.65	87.79	4983.87	5116.79	4994.69	4432.25
China	130.83	135.77	141.70	145.46	9297.99	9507.11	9825.80	9893.51
European Union	62.12	62.04	61.16	55.74	3124.80	3070.60	2944.70	2549.82
	Solar power generation consumption (EJ) from 2017 to 2020				Wind power (EJ) from 2017 to 2020			
the United States	0.70	0.84	0.97	1.19	2.31	2.46	2.70	3.03
China	1.06	1.58	2.00	2.32	2.74	3.27	3.62	4.14
European Union	0.95	1.01	1.11	1.30	2.80	2.86	3.26	3.51
	Renewable energy power generation consumption such as geothermal energy and biomass energy (EJ)				Oil consumption (million tons) from 2017 to 2020			
the United States	0.75	0.73	0.70	0.68	826.33	844.36	841.79	739.66
China	0.72	0.84	0.92	1.20	596.37	619.83	650.15	669.21
European Union	1.49	1.50	1.50	1.51	538.90	538.50	537.40	461.79
	Oil consumption (EJ) from 2017 to 2020				Natural gas consumption (EJ) from 2017 to 2020			
the United States	36.29	37.11	36.99	32.54	26.64	29.52	30.48	29.95
China	25.57	26.58	27.91	28.50	8.66	10.19	11.06	11.90
European Union	23.30	23.29	23.25	20.00	13.87	13.60	14.06	13.37
	Coal consumption (EJ) from 2017 to 2020							
the United States	13.87	13.28	11.34	9.20				
China	79.28	79.83	81.67	82.27				
European	9.49	9.09	7.48	5.95				

Union					

Data source: Statistical Review of World Energy July 2021，http://www.bp.com/statisticalreview

It can be seen from these data that the global energy consumption structure is changing. The traditional primary energy consumption such as oil, natural gas and coal is in a downward trend in the United States and the European Union, but China's demand for the primary energy is still on the rise, among which the coal is the energy that China depends on and the western countries are gradually getting rid of. It indicates that China's energy structure adjustment still faces huge pressure from coal. In terms of new renewable energy, the consumption of renewable energy in China, the United States, and Europe is constantly increasing, which indicates that there is still significant room for the global demand on renewable energy in the future. Renewable energy is an important source and growth point of global energy demand in the future.

3. Comprehensive comparison and analysis on the participation of major powers in energy governance

The disorderly development of the energy field needs to be constrained by global energy governance from the perspectives of market supply and demand, energy dependence, energy politics, environmental governance, corporate systems, social organizations, and international technical cooperation. The global energy governance system is a complex system of mutual constraints. Under this system, various major economies not only engage in geopolitical, political, military, economic, and financial game and competition around energy, but also coordinate and even cooperate in the fields of resource technology, sustainable utilization and distribution of resources, and price stability. The project research is based on literature and data survey and summary, and the system of "participation of major powers in global energy governance performance evaluation index" is established, and the comprehensive evaluation on the actual international leadership and future leadership performance of various countries in the process of global ecological civilization transformation is conducted in combination with the questionnaire evaluation (that is, "the participation of major powers in global energy governance performance evaluation") and data index evaluation (that is, "the participation of major powers in global energy governance index evaluation") . The index system is mainly divided into three levels. The first level is the dimensional level, that is, the four dimensions of economy, technology, society, and politics. The second level is the main fields under each evaluation dimension. The economic dimension mainly includes economic governance and market mechanisms; the technical dimension mainly includes technology development and evaluation standards; the social dimension mainly includes environmental responsibility and social governance; and the political dimension includes political allies, security governance, and mechanism building. The third level is mainly the specific evaluation content, including market equilibrium, GDP dependence on energy, price impact, corporate role, global energy market management, energy trade arbitration, offshore oil and gas development, energy internet, energy development technical standards, energy data and information control, carbon emissions and environmental regulation, climate change and clean energy cooperation, non-governmental organization participation, community governance and public interest, resource allies, collective action capability and dispute resolution in energy politics, maritime passages and major infrastructure facilities, emergency early warning, counter-terrorism and nuclear non-proliferation, energy dependence on foreign countries, participation in international treaties, leading energy related mechanisms, etc. The respondents of the questionnaire mainly include experts from the Ministry of Ecology and Environment, the Institutes of Science and Development, Chinese Academy of Sciences, the National Center for Climate Change Strategy and International Cooperation, the State Grid Energy Research Institute, the All-China Environment Federation, the Shanghai Academy of Social Sciences, the Shanghai Petroleum and Gas Trading

Center, and the Agora Energiewende, the Greenpeace and the energy research departments of the international non-governmental organizations. The performance of eight countries, including China, the United States, Japan, the United Kingdom, Germany, France, Russia, and India, in participating in global energy governance is evaluated by them through the specific evaluation content of the third level index.

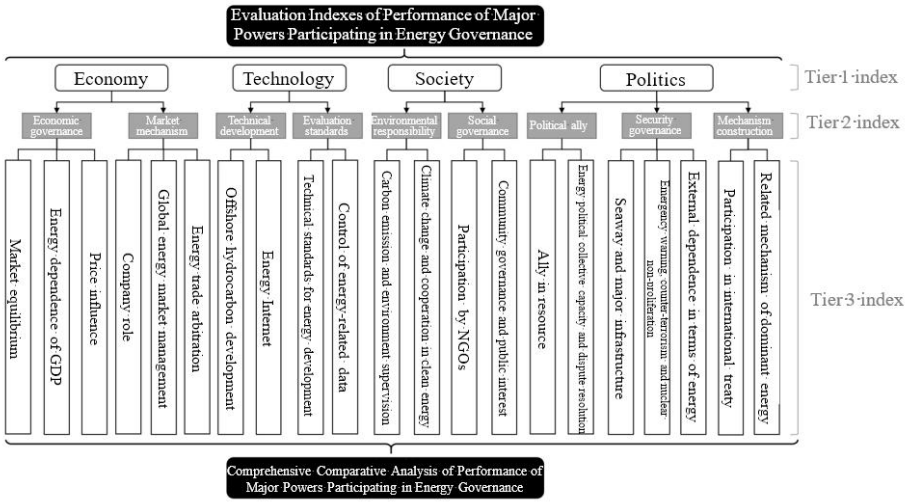

Fig. 1. Hierarchical Analysis of Participation of Major Powers in Global Energy Governance Performance Evaluation

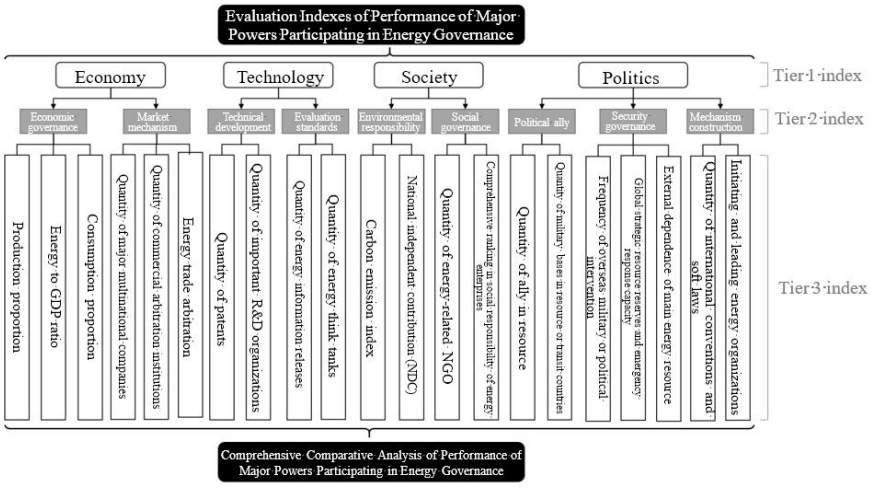

Fig. 2. Schematic Diagram of Major Countries Participating in the Evaluation System of Global Energy Governance Indexes

Based on the collected results of the above-mentioned “Performance Evaluation of Participation of Major Powers in Global Energy Governance” and “Indexes Evaluation of Participation of Major Powers in Global Energy Governance”, it is necessary to carry out Reliability & Validity, data standardization, correlation derivation and weight assignment. First, in this study, SPSS 26.0 software (IBM Corporation) was used to conduct factor analysis on 21 results of the above questionnaire and index evaluation. The Bartlett sphericity test was carried out to test the accompanying probability sig value and judge the feasibility of performing factor analysis. In the process of index evaluation based on data investigation, due to the different dimensions of each index data, all index data need to be standardized (that is, dimensionless). In order to ensure the sign consistency of performance evaluation (that is, the relationship between the scores of all indexes and the evaluation conclusion is positively correlated), Min-max extreme value standardization processing was adopted in this study. The processing formulas of positive indexes and reverse indexes are listed below, respectively:

$X_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}$ and $X_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}$

Among them, X_{ij} represents the standardized value of country i on the j indicator; $\max(x_{ij})$ is the maximum sample value of the indicator, and $\min(x_{ij})$ is the minimum sample value of the indicator.

Secondly, according to the 21 observation indexes selected in this study, the comprehensive performance was regarded as the dependent variable Y, and the equation was constructed based on X_{ij} as the independent variable to perform stepwise regression, and the variables were introduced successively, and finally the significance of the variables was tested one by one:

$$Y = \beta_0 + \beta_i X_i + \ldots + \beta_n X_n$$

Thirdly, there exists both similarities and significant differences in the means of participation in energy governance of various countries. In the study, the K-means algorithm (i.e., K-means algorithm) was used in dynamic clustering to conduct cluster analysis on the questionnaire results and index evaluation respectively. As a result, the main channels and core competitiveness of eight countries including China, the United States, Japan, the United Kingdom, Germany, France, Russia, and India, which affect their respective energy governance performance, were investigated respectively, and a longitudinal comparison was made (that is, the comparison between the questionnaire results and the index evaluation results of the same country) and side-by-side comparisons (i.e. comparisons between countries). Through vertical comparison, on the one hand, the scientific demonstration of reliability and validity verification was obtained, and on the other hand, the consistency of a country's climate governance means and goals were identified. By virtue of horizontal comparison, on the one hand, the differences in the paths of participating in energy governance and the acquisition of leadership in different countries were compared. On the other hand, it was used to identify key areas in which major countries participate in energy governance competition and cooperation.

Finally, based on the above analysis results, in this study, suggestions for China's participation in global energy governance were put forward, including advantages and disadvantages of China's current participation in global energy governance, the practical cooperation path for China's participation in global energy governance, and policy recommendations for China's participation in global energy governance.

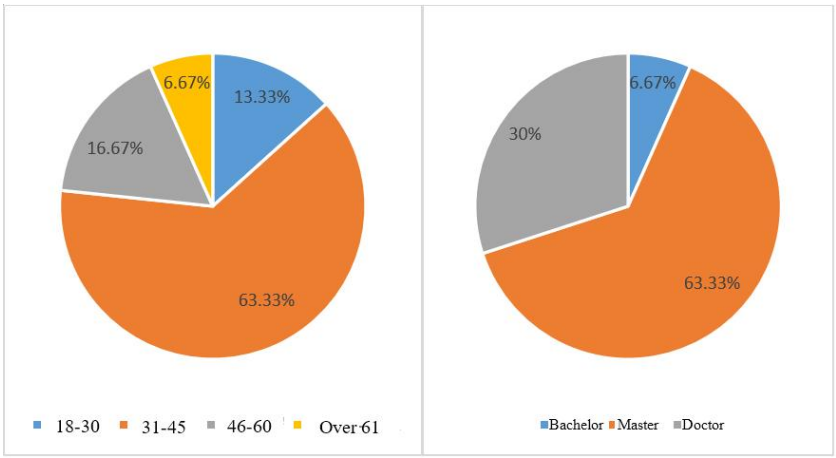

Fig. 3. Distribution of Age and Educational Background of Experts Participating in this Survey

The picture above shows the age and educational background distribution of the experts participating in this survey. Most of the experts participating in this survey are between 31 and 45 years old, and regarding academic qualifications, most of them have obtained master's degree or above.

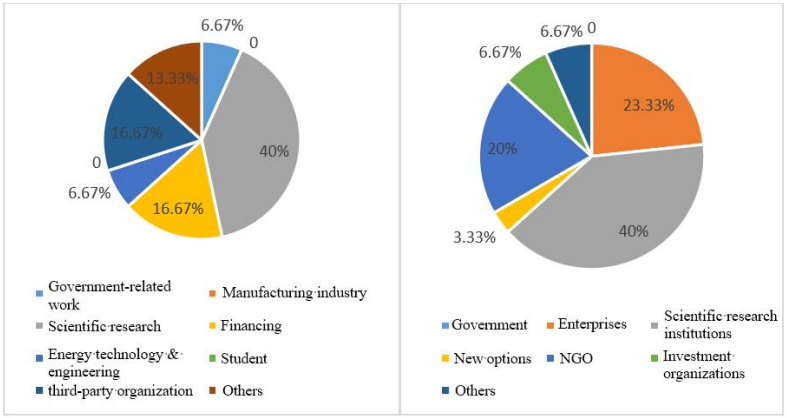

Fig. 4. Distribution of Professional Fields and Organizations of Experts Participating in this Survey

The picture above shows the professional field distribution and organization affiliation of the experts participating in this survey. It can be seen that the experts participating in the survey are mainly involved in scientific research affairs, followed by those engaged in financial affairs or third-party service agencies. The smallest proportion indicates those who carry out related work with government departments expert.

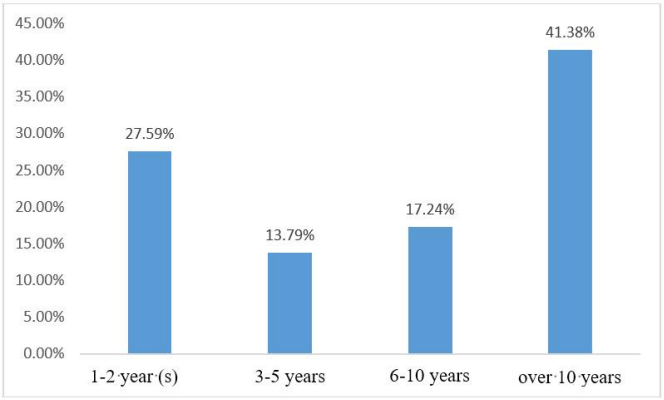

Fig. 5. Time Distribution of Participation in Energy Industry Related Affairs

The above picture shows the time distribution of experts involved in energy industry-related affairs. It can be seen that most of the experts participating in this survey have been engaged in related affairs in the energy field for more than 10 years, and about 75% of the experts have at least 3 years of relevant work experience, having accumulated relatively rich experience in the basic situation of energy in various countries and in some professional branches.

4. Conclusions and analysis

Through experts' questionnaire survey results based on the three-level indexes of the "Major Powers Participation in Energy Governance Evaluation" system, it was sorted out into a comprehensive performance in various dimensions. As shown in the table above, the comprehensive performance of major powers participating in energy governance in the four main dimensions of economy, technology, society, and politics, as well as the overall performance of participating in energy governance after weighting, have been listed in the form of scores. Weighting coefficient was used to calculate the conversion value for the total score of single dimension evaluation according to the equal distribution of scores in each dimension. In terms of total scores, the USA performs the best in participating in global energy governance, with a score of 76.75. While China, Britain, France, Germany, and Japan are relatively close regarding the score, all within the range of 60-65. Russia and India are in the third and fourth place, scored 55.7 and 45.9 respectively. In the above four dimensions, India ranks the last, and its evaluations on the third-level indexes are also the lowest among all countries, so it will not be repeated in the following summary of performance evaluation comparisons.

Table 2. Index Scores and Total Scores of Major Powers Participating in Energy Governance of Different Dimensions

	USA	China	Britain	France	Japan	Russia	India	German
Economic dimension	19.04	15.46	15.63	15.54	15.21	15.75	12.79	16.29
Technological dimension	20.19	17.50	16.31	15.06	15.19	14.00	11.25	15.06
Social dimension	17.13	15.19	17.81	17.31	15.94	11.38	10.88	18.19
Political dimension	20.39	15.96	16.14	15.93	14.71	14.57	10.96	16.39
Total scores	76.75	64.11	65.89	63.85	61.05	55.70	45.88	65.93

In terms of economic dimension, compared with other countries, the United States has the best performance in performance evaluation in five indexes: market equilibrium, energy governance to resist price influence, the actual role of American enterprises in global energy governance, the influence of global energy market management and the influence of international energy trade arbitration, with the reflection of the most improved economic governance and market mechanism of the US compared with that of other countries; The impact degree of China's GDP on energy dependence is relative minimum, but the ability to resist price influence in energy governance is relatively weak, with the reflection of the need of paying attention to balanced development in the economic governance for China; Compared with China, Japan, Russia and India, the performance of Britain, France and Germany in terms of market equilibrium and price impact are better, but they possess the GDP highly dependent on energy, relatively lower than the US, Germany, China and Russia in the influence of global market management and energy trade arbitration. However, apart from the US, German has the relative best performance in such four aspects, which reflects that Britain and France are closer but Germany is relatively different in the economic governance of European countries. In addition, Britain, France and Germany have different capabilities in market mechanism, and Japan performs relatively poorer compared with them, with the un-strong economic governance capacity as well; Russia has a relatively uneven market performance in the energy governance, with the GDP less dependent on energy, and Russia has the largest influence in global market management apart from the US, which reflect that Russia has a good market mechanism but cannot fully reflect the expected effect of its mechanism in economic governance.

In terms of technological dimension, compared with other countries, the US gains the best performance evaluation in the participation of offshore oil and gas development degree, energy development technical standard discourse power and energy data information ability, with the refection of the United States possessing a strong speaking right in technology development and evaluation standards; China has the relatively most developed degree in energy Internet research and development and application and embodies a strong competitiveness in offshore oil and gas development and technical standards as well, with the reflection of the need of increasing speaking right and leadership in the national standard for China in the future; Compared with France, Germany and other European countries, The UK possesses the better performance in offshore oil and gas development and data information capabilities, however, France and Germany have no outstanding governance performance in the technical dimension. On the contrary, compared with other countries, France and Germany have the lowest performance evaluation, with reflection of the differences in technological development routes and the similarities in evaluation standards of European countries; Compared with other countries, Russia has a poor performance in internet research and development and application, which reflects that the capability of technological development is focused by Russia, but the influence on the technical dimension is not its focus of work.

In terms of social dimension, among the major powers, the US gains the best evaluation of performance in non-governmental organization participation and community governance and public interest acquisition, but in the middle of the pack of overall performance on carbon emissions and environmental regulation and participation degree in global cooperation on climate change and clean energy compared with other countries, with the explanation of strong ability of social

governance of the US but its reluctance to accept environmental responsibility; With the good performance evaluation in four indicators, Britain, France and Germany gain the best performance evaluation in overall performance of carbon emission and environmental regulation as well as community governance and public interest, reflecting the positive attitude of European countries in environmental responsibility and social governance; China is more involved in global cooperation on climate change and clean energy but has the performance at the midstream level in the other three indicators, which reflect that China has carried out a lot of work in terms of environmental responsibility but still needs to take multiple subjects or stakeholders into consideration in social governance; Japan has a good performance in community governance and public interest acquisition but has the performance at the midstream level in the other three indicators, with the reflection of the similar position but generally weak social influence of Japan and the US; Apart from India, Russia has the worst performance evaluation in three-level index of all social dimensions.

In terms of political dimension, the US gains the best evaluation in seven indicators including the ability of uniting resource allies, influence of energy political collective action and dispute settlement, ability of security governance on sea lanes and major infrastructure, ability of security governance on emergency early warning, counter-terrorism and nuclear non-proliferation, degree of energy external dependence, degree of impact on global energy governance brought by the launching of international conventions or soft laws, and the ability of initiating and leading energy-related mechanisms, with the reflection of the strong competitiveness of the US in political allies, security governance and institution building; With the good ability of infrastructure security, emergency management, influence of international rules and the ability to initiate a dominant energy mechanism, China does not show the strong competitiveness in uniting resource allies and its energy dependence on foreign countries is relatively high as well; With the relatively close evaluation in resource alliances, collective action, infrastructure security, emergency management, international rules and energy regimes, the three European countries of Germany, Britain and France are in the second tier apart from the US in performance evaluation as well, showing that European countries have similar positions on political allies, security governance and mechanism building; Japan has a relatively strong performance in the ability of uniting resource allies, with the relatively high energy dependence on foreign countries, due to the high correlation between the both; Russia has the relatively poor overall performance on the political dimension, mainly reflecting in four aspects including resource allies, infrastructure security, international rules and energy mechanism, but it has the relatively low energy dependence on foreign countries, just next to the US.

5. Outlook

Along with the continuous development of globalization, the health of the earth system has been affected by the threat to climate environment, and climate governance has become an important aspect of global governance, with the formation of the situation of climate cooperation, game and competition between major powers, especially China, the US and Europe. There is increasing divergence between different countries, especially developed and developing countries, and unprecedented difficulties are faced by the global climate governance, due to the constant appearance of deep-seated contradiction between human and nature. With the increasingly obvious variation trend of global energy supply and demand market structure and the further highlight of geopolitical situation of energy, technological innovation in the energy industry has led to rapid development of clean energy and deepened the correlation degree of energy security, global economy, climate environment and climate security. In the next five to ten years, China will enter the middle and late stages of industrialization, with the energy security of one of the key factors to ensure future peaceful development. Under the background of great adjustment of energy structure, the problems of high dependence on foreign countries and large concentration of imports are faced

by China, and multiple challenges including increased geopolitical risks, increased risks in energy transportation routes, and capacity building in energy finance are faced as well. With the maintenance of China's energy security from a multi-dimensional perspective, we need to think about and formulate reasonable and efficient energy policies.

Firstly, with respect to the future global energy pattern across-affected by the pandemic, geopolitics and geo-economics, the low oil price can reduce energy costs in manufacturing powerhouses like China, thus providing the necessary energy support for their post-pandemic economic recovery. However, the low oil price will impact the oil industry, affect the political, economic and social stability of the Middle East, and bring other linkage effects and other risks and crises.

Secondly, with the China's resource imports mainly relying on the supply from overseas, especially since 2015 to 2019, China has had significant growth in import volume of major minerals, and its import concentration and dependence are both rising. Oil, coal and natural gas resources mainly come from the Middle East, Russia, Mongolia, Australia and Indonesia; Iron, aluminum, copper and rare metals mainly come from Australia, Brazil, Philippines, Indonesia, Chile, Peru and other countries. Therefore, one of the major issues that China's diplomacy needs to face is how to dispose relations with traditional powers in the field of resources.

Thirdly, with the increasing nervous Sino-US game and the existing huge uncertainty, the US and European Union have the synchronous development with China's competition and cooperation in terms of global order, economic dominance, energy security, scientific and technological innovation in the field of climate change. China can strengthen cooperation with major economies on green governance within the framework of the United Nations, the G20 and the Belt and Road Initiative, follow the trend of multi-center, multi-department and multi-level governance of global climate governance, and form the global climate governance pattern featuring extensive consultation, joint contribution and shared benefits, thus preventing the differences of ideas and interests between big countries and between departments and promoting the effect of global climate governance. Moreover, the experience and plans for promoting environmental protection and high-quality economic development can be provided for more developing countries, and the operation with other countries can respond to global environmental issues to achieve the complicity of global ecological civilization and joint-construction of the earth ecological home and human community with a shared future.

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