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Objectives and strategies for energy revolution in the context of tackling climate change

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Abstract

Global climate change mitigation and CO_2 emission reduction have promoted the revolutionary transformation in energy system. The core content of energy system revolutionary transformation is to replace the high-carbon energy system dominated by fossil energy with low-carbon energy system dominated by new and renewable energy and finally realize the near-zero emission of CO_2. The new energy system transformation has also led to a reform in global economic and social development patterns. Developing low-carbon economy becomes the fundamental strategy of sustainable development under climate risk management and the only solution to getting on the road from industrial civilization to ecological civilization. China intends to achieve the peaking of CO_2 emissions around 2030 and increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030. Guided by the targets, China directs its economy development to a low-carbon pattern. Therefore, new and renewable power capacity need to reach 1300 GW, and the electricity generated should be 4 times of that in 2013 with a continuous increase rate of 6%−8% around 2030. The pace of energy substitution need to be accelerated and efficient, safe, clean, and low-carbon energy supply and consumption systems should be established besides strengthened energy conservation and improved energy efficient. Therefore, reform need be deepened, favorable policy system and market mechanism for energy revolution and low-carbon development need be established, energy pricing mechanism should be reformed, and national carbon market should be formed to provide a favorable policy and market environment for low-carbon technology innovation and industry development.

Keywords: Climate change; Energy revolution; Low-carbon development; CO_2 emission reduction

1. Introduction

Climate change is the biggest threat to human today and will jeopardize the ecological security of the Earth and well-being of humans. Since the United Nations Framework Convention on Climate Change (UNFCCC) was established in the United Nations Conference on Environment and Development in 1992, the world has begun to cooperate on combating climate change. The core of mitigating climate change is reducing greenhouse gas (GHG) emissions by anthropogenic activities, stabling the GHG concentration in the atmosphere, and controlling the temperature rise on the Earth's surface to protect the Earth's ecological security and the sustainable development of humans. This controlling and management of natural risks during the development of human society provide a path to realize the harmony of economic and social development and natural and ecological environment protection. The key to realize those objectives is promoting the revolutionary transformation in energy production and consumption, developing and establishing a new efficient and low-carbon energy system dominated by renewable energy, and finally realizing near-zero CO_2 emission so as to free the

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development of human society from the limited mineral resources, prevent pollution emission into the Earth's environment and coordinate economic and social development goals and protection of the Earth's ecological environment.

2. Energy system revolution driven by global climate change mitigation

The 2009 Copenhagen Climate Conference has reached a consensus to hold the increase in global temperature below 2 °C. The IPCC Fifth Assessment Report released in 2014 emphasized the emission reduction pathway of controlling global temperature rise within 2 °C on a basis of the scientific conclusion that anthropogenic GHG emissions are the main cause of climate change. It is emphasized that the global carbon emissions need to peak around 2020, to decrease by 40% by 2030 which equals the emission level of 2010, to cut by 40%−70% around 2050, and to realize near-zero emission at the end of the 21st century. On the other side according to the emission reduction commitments and development trends of the countries, there is still a 5−10 billion tons of CO_2 emission reduction gap by 2020, and the global emissions will be 30% more than the amount of 2010 by 2030. The temperature rise will then be 3.7−4.8 °C at the end of this century, and will lead to catastrophic consequences to nature and human society (IPCC, 2014). Therefore, it is necessary for all countries to reduce more emissions and the world's economic and social development will face serious challenges of limited emission spaces. The ongoing Durban platform negotiations will reach a new agreement on the post-2020 climate convention framework regarding all countries in the end of 2015. As the situation of climate change mitigation becomes more serious globally, all countries will have to take more ambitious actions on emission reduction.

The core content of climate change mitigation is to reduce GHG emissions, mostly CO_2 emissions in energy consumption. Fossil energy consumption is the main source of GHG emissions and the field of emission reduction which is closely related to economic and social development. Realizing CO_2 emissions control goals while maintaining sustainable economic and social development needs the revolutionary transformation of the energy system, which is two-fold. First, strengthening energy conservation and improving the efficiency and economic benefits of energy utilization technologies to slow down the energy demand growth rate while maintaining economic development. Second, developing new and renewable energies such as hydro, wind, solar, biomass, and nuclear powers, upgrading energy mix and cutting the share of fossil energy such as coal and oil to reduce CO_2 emissions while ensuring energy supply. The two aspects above constitute the goals and the main paths of energy transformation. Finally the sustainable and low-carbon energy system dominated by new and renewable energy will replace the high-carbon energy system dominated by fossil energy, and near-zero CO_2 emission will be achieved.

The urgency of combating climate change globally has accelerated the pace of global energy revolution. Big nations have implemented new energy strategies and set advanced energy efficiency standards, energy conservation objectives as well as renewable energy development goals. For example, the European Union targets at a 20% increase in the energy efficiency by 2020 compared with 1990 levels. Germany plans to reduce primary energy consumption by 20% and 50% respectively against 1990 levels by 2020 and 2050, and with the continuing economic development, the share of renewable energy would reach 30% and 60% respectively by 2030 and 2050. Therefore the energy consumption related CO_2 emissions would reduce by more than 80%. The U.S. also sets the technology standards for light passenger vehicle to increase the fuel economy by 80% and reduce the CO_2 emissions by more than 40% by 2020 compared with those at present; moreover, commercial and industrial buildings will have a 20% energy efficiency increase by 2020. By 2030, the CO_2 emissions in the present electricity stations in the U.S. would be 30% less than the 2005 level. Currently the GDP growth of developed countries is relatively slow, which enable them to support the continuous economic growth by improving energy efficiency. Besides, their CO_2 emissions tend to decrease continuously due to stable total energy demand and adjustment in energy structure. As for developed countries in Annex II of the UNFCCC, GDP has increased by 5.3% while primary energy consumption decreased by 6.6% and renewable energy supply increased by 20% from 2005 to 2011, resulting in a CO_2 emission reduction by 8.2% (IEA, 2014; BP, 2014). Future economic recovery would possibly accelerate the GDP growth in developed countries, but their total energy consumption will be stable and the CO_2 emissions will keep decreasing. On the other hand, due to rapid industrialization and urbanization, developing countries' total energy demand would continue to increase, leading to the increasing fossil energy consumption and related CO_2 emissions for a long time in spite of rapid renewable energy development. Therefore, it is more difficult for developing countries to decarbonize energy mix compared with developed countries.

Global energy transformation has promoted the innovation and development of low-carbon energy technologies, and advanced energy technologies are now becoming a hot field of international technology competition as well as a reflection of a nation's core competitiveness. Developed countries actively promote energy transformation and reduce CO_2 emissions to increase their industrial low-carbon competitiveness, enhance the diversity of energy mix and decrease dependence on fossil energy as well as secure energy supply. Moreover, taking advantage of the globally low-carbon development trend and their advanced technologies in renewable energy and energy efficiency promotion, developed countries actively enlarge their market in developing countries, seeking new economic growth points and opportunities of benefit, and gaining competition advantage in the world economic and technological competition. Under such a situation, China has to actively take part in the competition, strengthen the R&D (research and development) and accelerate the industrialization of advanced energy technologies, and take control of the core technologies to win the market by utilizing the advantage

of a large domestic market capacity. Only by actively promoting the energy system transformation and establishing an industrial system featuring low-carbon emissions, China can gain the advantage in global low-carbon development competitions and play an active role in international negotiations.

3. Radical transformation in development concepts and patterns led by global climate change mitigation

The energy transformation trend faced by the world is regarded as an important symbol of the upcoming Third Industrial Revolution (Rifkin, 2011). Every industrial revolution in the history has been driven by the revolution in energy and power. In the first industrial revolution, coal replaced firewood, the invention of steam engine led to industrialized production of industrial products such as textile, and the labor productivity grew dramatically due to the emergence of railways. In the second industrial revolution, electricity was invented as secondary energy, and industrial products were intensively and automatically produced on a large-scale, for example, the Ford automatic motor production lines. Oil replaced coal and internal combustion engines appeared. More convenient transportation and communication tools came into being, such as automobiles, planes, telegram, and telephone, which dramatically improved the labor productivity again. However, the first and second industrial revolutions both caused the endless consumption of the Earth's mineral resources and fossil energy and waste emissions to the environment. They led to the gradual exhaustion of the mineral resource and ecological crisis represented by global climate change while creating a highly developed industrial civilization. Industrial civilization is an unsustainable form of human society. Population in developing countries is now several times more than that of developed countries, therefore, the resource and environment do not allow developing countries to copy the fossil energy-supported high-carbon development path led by the developed countries in their modernization process. The world now urgently needs a transformation to an ecological civilization where human and nature exist in harmony. Therefore a green and low-carbon sustainable development path is needed (Rifkin, 2011; He, 2014b).

Global climate change mitigation and GHG emission reduction will lead to revolutionary transformation in the economic and social development patterns. Developing low-carbon economy is now becoming a worldwide trend. In low-carbon economy, high economic development level, high social productivity, and high living quality are supported by low energy consumption, low pollution, and low emissions. The new energy system revolution is featured by replacing fossil energy with new and renewable energy. It is not only a fundamental way to develop low-carbon economy and coordinate economic and social development and resource and environment protection, but also a key strategy for combating climate change.

Climate change mitigation and establishment of ecological civilization will lead to innovations in the development and consumption concepts: from the industrial civilization development concept of merely pursuing economic output and production efficiency to the ecological civilization development concept of realizing harmonious and sustainable development of human and nature, economy and the environment, as well as human and the society; from the consumption concept of welfare maximization of excessive pursuit of material comfort to a healthy and appropriate consumption concept focusing more on spiritual and cultural civilization; from the pursuit of GDP growth, individual wealth accumulation and material comfort to the balanced development of economic growth, social progress, and environmental protection and the quality and benefit of economic and social development. The development of economy will not excessively take resource from and emit pollution to nature, but will seek for a comfortable living environment in which human and nature would exist in harmony to make good ecological environment the most universal public product and the most equitable social well-being. High-level living quality needs to be shared by all, and experienced by all, because it will boost accumulation and sharing of public fortune, and create favorable conditions for cooperation and multi-win−win situations among countries in the world and classes in the society. Therefore, the development theory and assessment methodology of conventional industrial civilization will no longer be suitable for the development ideology and target of the ecological civilization: new development theory and assessment methodology suitable for ecological civilization will emerge and develop (He et al., 2014).

Economic development, social progress, and environment protection are three inter connecting pillars of sustainable development. To combat climate change and protect the environment while maintaining economic and social sustainable development, the world will be facing a severe situation because the carbon emission space is limited. Carbon emission permit will become a more scarce public resource and a production factor more important than labor, capital, land, and other scarce resources. The basic solution to resource and environmental limit and harmonious development of the human and nature will be increasing the economic output of unit carbon emission. Carbon price under the widely developed carbon tax and carbon market mechanism will monetize the environment value and internalize the social cost of environment bearing capacity utilization. It will also lead the social funds to energy conservation and new energy technologies and promote energy system revolution and decarbonization of economy and society. The key of climate change mitigation under a sustainable development framework is to sharply increase the carbon productivity. The carbon productivity is the ratio of the GDP and total CO_2 emissions of a year, reflecting the output of unit CO_2 emissions. To limit the temperature rise within 2 °C while maintaining a stable GDP growth globally, carbon productivity would be 1.5−2.0 times that of the 2010 level by 2030, with the annual increase rate of 4.5%−5.5%, a lot higher than the growth rate of labor productivity since the first industrial revolution. As a matter of fact, the annual increase rate of global carbon productivity has been only 0.7% from 1990 to 2011, with the annual growth

rate being 2.0% for the Annex I countries and 4.4% for China (He et al., 2010). Therefore it is necessary to seek for measures to greatly increase carbon productivity, to investigate the patterns of carbon productivity increase in countries of different development stages, to analyze the way and roadmap of carbon productivity increase, and to explore the path of realizing low-carbon development.

The process of global climate change mitigation will also promote the reform and establishment of mechanisms for global sustainable development and climate management. While managing climate risks, it is necessary for global climate management mechanism to coordinate multiple targets of economic development, social progress, and environment protection. It should take energy reform as new development opportunities, new economic growth points and new job opportunities as well as priority area and domestic demand of sustainable development, which promotes transition to a green, low-carbon and sustainable socioeconomic development pattern for each country against the background of global climate change mitigation. As for international regime, it is important to focus on sharing development opportunities and promoting international cooperation and technology transfer and mutual benefits instead of only discussing the emission reduction responsibility under intergenerational and international equities in order to lead most countries to a green and low-carbon sustainable development path while limiting the global temperature rise within 2 °C. Just as mentioned in the *China-U.S. Joint Announcement of Climate Change*, "smart action on climate change now can drive innovation, strengthen economic growth and bring broad benefits — from sustainable development to increased energy security, improved public health and a better quality of life. Tackling climate change will also strengthen national and international security" — there are many great opportunities for cooperation.

4. Objectives and strategies of energy revolution for China's climate change mitigation

Since the reform and opening up, China has achieved remarkable economic development, while generating large energy consumption with rapid development. From 1990 to 2013, the energy intensity of GDP has decreased by 59% and CO_2 intensity has decreased by 62%, which are much higher than those in developed countries. Meanwhile, China's GDP increased to 9.3 times, resulting in an increase of CO_2 emissions to 3.8 times. The CO_2 emissions due to energy consumption now account for more than 25% of the world total emission. Fossil energy — such as coal — consumption increases in a high rate, and is pushing the resource support and environment bearing capacity to limit. In 2013, China's coal production reached 3.68 billion tons, exceeding the scientific production supply capacity by almost one time, resulting in the land subsidence of over 1 million hectares accumulated, as well as more severe underground water resource damage and air and Earth pollutions. Fossil energy — especially coal — consumption is also the main source of conventional pollution emissions such as SO_2, NO_X, and soot. Coal combustion and vehicle exhaust emissions are the main causes of the severe smog in the Beijing−Tianjin−Hebei region. China's import of oil and gas are increasing, reaching 58% and 31% of total consumptions respectively in 2013 — energy supply security is facing new challenges (NBSC, 2014).

Given the situation of tight resource limitation, severe environment pollution and degradation of ecological system, strengthening energy conservation, promoting energy efficiency and restructuring energy system are not only the domestic needs for China to break the resource and environment limitation, establish ecological civilization and achieve sustainable development, but also strategic options to actively promote global climate change mitigation. Promoting energy production and consumption revolution has dual effects of boosting energy conservation and substitution, which help to reduce conventional pollution emissions such as SO_2, NO_X, $PM_{2.5}$ while cutting CO_2 emissions. Particularly, by implementing the total energy consumption controlling objective, total coal consumption would be effectively controlled, which will reduce environmental pollution from the source. Therefore, promoting energy production and consumption revolution would become the key point and an integrated measure of energy conservation, energy restructuring, ecological environment protection, and climate change mitigation, and will show significant co-benefits. That will also effectively transform the high-carbon development pattern featured by resource dependence and extensive expansion to a low-carbon one featured by innovation and inward improvement, promoting the progress of ecological civilization.

In terms of domestic need, the target of energy revolution is to establish efficient, safe, and clean energy supply and consumption systems to support sustainable socioeconomic development. Global climate change mitigation action pays more attention to the decarbonization of energy supply and consumption systems as well as the aims and measures of CO_2 emission reduction. China's energy revolution strategy needs to combine the two aspects, not only focusing on energy conservation, environmental protection and energy security, but also on CO_2 emission reduction objectives, measures and effects. Decarbonization should be included in the strategic targets of energy revolution while making full use of the co-benefits. Establishing efficient, safe, clean, and low-carbon energy supply and consumption systems should be regarded as strategic objectives coordinating domestic sustainable development and global climate change mitigation.

China is now experiencing rapid industrialization and urbanization, and its energy demand will continue to increase for a long time. The priority at present is to increase the output value of unit energy consumption and unit CO_2 emissions, which means increasing the carbon utility, or decreasing the energy intensity and CO_2 intensity of GDP. China's energy consumption in 2014 was approximately 22.4% of the world total, while its GDP was only 12.3%. China's energy intensity of GDP was 1.8 times of the world average level (IEA, 2014; NBSC, 2014), and 3−4 times of the level of developed countries, which indicates a large potential to decrease.

The distance between China and developed countries is not far in terms of efficiency of energy conversion and utilization technologies, and the gap is diminishing in recent years. For example, China's efficiency of coal-fired power generation is now higher than that of the U.S., reaching the world advanced level. The main reason for China's low output value of energy lies in its ongoing industrialization, with industry taking almost 50% of the GDP, much higher than the 30% share in developed countries. China's industrial energy consumption accounts for 70% of the total final energy consumption, while that share is usually less than 1/3 in developed countries. What's more, China's manufactures are in the mid-low end of the international value chain with high energy consumption and low value added. The above structural factors in industry and products both lead to China's high energy intensity of GDP. The proportion of China's secondary industry in its GDP now reaches or exceeds the peak level of developed countries in industrialization stage, besides, the output of its products such as iron and steel, cement, and household appliances reaches half of the world total, thus, China has the space and potential to restructure and reduce the energy intensity of GDP considerably. According to calculations, if the share of industry in GDP decreases by one percent while that of service increases by one percent, energy intensity of GDP would decrease by one percent. Therefore, while promoting energy saving technologies, closing outdated production facilities, and promoting upgrading of industrial technologies as well as continuously increasing the energy utilization efficiency, it is also important for China to develop strategic emerging industries and modern service industry, limit the export of energy-intensive, pollution-intensive, and resource-intensive products, and foster upgrading of industrial technologies and save energy through industrial restructuring.[1] China's exports are mostly low-end productions with high energy consumption and low value added. The energy consumption of export goods takes up 25% of the total energy consumption in China, and the net implied energy consumption of exports is still over 10% of the total after the import and export implied energy consumptions offset each other. Therefore, it is important to abandon the extensive growth pattern driven by continuously increasing investment, expanding heavy industry capacity and increasing manufacture export and to highlight the pulling effect of final consumption, because they would both help to slow down the demand increase in energy-intensive commodities such as iron, steel and cement, to cut the share of energy-intensive industry, to foster industry restructuring and to establish a low-carbon industry system, therefore decreasing the energy intensity of GDP and promoting a green and low-carbon transformation of the economic development pattern.

During APEC in November 2014, China and the U.S. jointly put forward the *U.S.-China Joint Announcement of Climate Change*, setting post-2020 emission mitigation goals for both countries. China intends to achieve the peaking of CO_2 emissions around 2030 and to make best efforts to peak early and intends to increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030 (Han et al., 2012). That is a mid-and-long term strategic objective on energy revolution for China. It is positive and in want of efforts to achieve. It will also be an integrated goal for China to promote economic development transformation and global climate change mitigation, and needs forward-looking deployment as well as all-round coordination.

China will generally complete industrialization and urbanization around 2030 — the economy tend to grow inward, and the GDP growth rate will be lower. Besides, China would continuously reinforce energy conservation and substitution. With a slow increase of energy demand, China would add new and renewable energy supply to satisfy the increment of total energy demand so as to prevent the fossil fuel consumption growth and achieve the peaking of CO_2 emissions. Even with great efforts in energy conservation, China's total energy demand will amount to around 6 billion tce around 2030, which is 40% more than that in 2013. Therefore, the 20% share of non-fossil energy target indicates a 1.2 billion tce supply. The installed capacity of non-fossil power needs to exceed 1.3 billion kW, which is 4 times of that in 2013. China's potential annual GDP growth rate will surpass 4% around 2030. By energy conservation and consumption control, the energy consumption elasticity is likely to decrease to about 0.3. Energy demand will grow by 1.0%−1.5%, with its new increment of energy demand satisfied by non-fossil energy to stop the CO_2 emissions from increasing. That means a 6%−8% increase rate of non-fossil energy. Besides, the new installed wind power, solar power, and nuclear power will be 20 GW, 20 GW and 10 GW respectively each year, of which the speed and scale of development far exceed other countries (He, 2014a). Because the construction and utility of energy infrastructure cover a long time and has technology locked-in effects, it is necessary to carry out forward-looking deployment and implement step by step in the 13th, 14th, 15th Five-Year Plan (FYP) periods.

The share of new and renewable energy will account for about 20% around 2030. By then the technology tend to be mature and the industry is competitive. With the stabilization of total energy demand, energy substitution will be accelerated. Non-fossil energy will account for 1/3−1/2 in primary energy in 2050. The share of coal will decline to below 1/3, and the share of natural gas will increase, reducing the CO_2 intensity of energy consumption by more than 40% from 2010 to 2050. Total CO_2 emissions will also show an obvious decline compared with the peak level (He, 2014a; CAE, 2011). All these will lay a foundation for the low-carbon sustainable energy system dominated by new and renewable energy in the second half of this century and the near-zero emission by the end of this century, which is aimed by global climate change mitigation action.

5. Policy and measures for China's energy revolution

The objectives on reducing energy intensity and CO_2 intensity of GDP were implemented during the 12th FYP

[1] http://news.xinhuanet.com/energy/2014-11/13/c_127204771.htm.

(2011−2015) period. Currently, China releases the Intended Nationally Determined Contribution (INDC) and intends to reduce the CO_2 intensity of GDP by 60%−65% against the level of 2005 by 2030. That need be put into practice step by step during the 13th, 14th and 15th FYP periods. What's more, in order to achieve the peaking of CO_2 emissions, the intensity controlling would expand to intensity and total amount controlling mechanism from the 13th FYP, and gradually shift to the guiding target of total CO_2 emissions constraint to promote the transformation of economic development pattern.

The CO_2 emissions from the industry sector account for nearly 70% of China's total CO_2 emissions. During the 13th FYP period, demand for energy-intensive products such as cement and iron and steel would stabilize because of economic transformation. CO_2 emissions from industry sector could reach the peak around 2020 through accelerating industry restructuring, transforming, and upgrading and widely distributing advanced energy conservation technologies. CO_2 emissions from the building sector account for 20% and the share will increase. In spite of that, through controlling total construction area, improving energy efficiency standards and developing new distributed energy, the CO_2 emissions from the building sector could peak around 2035. The CO_2 emissions from transportation sector take up 12% of the total, and will also have a rapid increase. However, through optimizing transportation structure, promoting fuel efficiency and substitution, and strengthening logistics management and optimization, peaking of the CO_2 emissions from transportation sector could be achieved around 2040. To ensure the peaking of total CO_2 emissions around 2030, industry, construction, and transportation sectors need to work out strategies and plans to save energy and control CO_2 emissions and promote reform.

It is important for the energy supply sector, especially the power sector, to decarbonize the energy mix and foster new and renewable energy development to achieve zero-growth of coal before 2020, control the peak coal consumption at 4−4.5 billion tons, and ensure the achievement of targeted share of the non-fossil energy. While tackling smog, the east coastal regions which are more developed should control and further reduce coal consumption, promote industry transformation and upgrading to reach the CO_2 emissions peak around 2020 and achieve the low-carbon transformation ahead of the other parts of China (He, 2014a; DRC, 2013).

Technology support is necessary for promoting energy revolution in China. While strengthening the research and development and industrialization of renewable energy technologies such as solar power, wind power, biofuel, it is also necessary to develop energy storage and smart grid as well as distributed energy system to strengthen the absorption, transmission and distribution capacity of the on-grid large-share renewable power, securing the stable operation of the power grid. The cost of renewable energy power is higher, thus feed-in tariffs would be given when the grid purchases the renewable energy power. While in the long term, the cost would be cut and the grid parity would be achieved around 2020 so that it can compete with traditional powers. Nuclear power will play an irreplaceable role in the process of energy system transformation. Because nuclear power is mature in technology, stable in operation, high in load factor, and cost-competitive, it can operate as the base load to support the stable operation of the power system. China intends to achieve the goal of 20% share of non-fossil power by 2030, of which the share of nuclear electricity would be more than 25% with an operational capacity of about 150 GW, substituting 0.5 billion tons of coal and reducing 0.9 tons of CO_2 emissions. New nuclear power generators adopt the advanced third-generation technology and the most strict safety standard, therefore the safety of large-scale nuclear power development is guaranteed. The CO_2 Capture and Storage (CCS) technology should be attached great importance while shifting the energy mix. Coal will dominate China's primary energy for a long time, which is expected to account for 50% by 2030. Under the tight carbon constraint and high carbon price, CCS will become a crucial option around 2030 with the clean and efficient utilization of coal. It is likely to reduce 1 billion tons of CO_2 annually through the utilization of CCS technology after 2030, which is important for achieving the long term CO_2 emission mitigation. Research and development and demonstration projects concerning CCS need to be furthered. Compared with coal, natural gas is cleaner and more efficient, and the CO_2 intensity of energy is 40% lower. Therefore, conventional and unconventional natural gas technology breakthroughs will also have important impacts on energy restructuring (He, 2014a; Du, 2015).

In addition, favorable system and mechanism of low-carbon development are needed to establish. It is necessary for all sectors and all regions to speed up their energy revolution. They should take energy conservation and CO_2 emission mitigation objective as comprehensive indicators and key points of coordinating domestic economic development transformation and global climate change mitigation. Support on industrialization of new energy technology innovation should be strengthened to improve the competitiveness of core technologies. Moreover, it is necessary to change the fiscal and financial policy system, the energy product pricing mechanism, and the resource and environment tax and fee system to promote the low-carbon development, to reinforce the energy market mechanism revolution, and to establish a national carbon trading market. In addition, low-carbon living style should be promoted and the low-carbon urbanization path of Chinese characteristic need be explored.

The cooperation process of global climate change mitigation and trend of global energy revolution provide China with a nice environment for international cooperation and an opportunity of win−win situations in energy production and consumption revolution. China needs to promote international cooperation, implement its Go Out policy in all aspects under the new situation, enhance the capability to obtain and utilize international resource, while developing energy enterprises with international competitiveness, strengthening the pricing power in international energy market, and actively taking part in the construction of international energy security system. Promotion of international energy cooperation not only needs the obtaining and utilization of international resource and the

ensuring of energy supply security, but also needs the promotion of international technology cooperation and technology transfer. What's more, international energy cooperation also brings an important opportunity for China to promote South−South cooperation and to strengthen the capacity of developing countries to combat climate change.

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