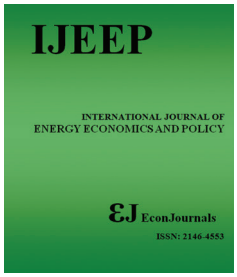

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Low Carbon Technology Innovation, Carbon Emissions Trading and Relevant Policy Support for China's Low Carbon Economy Development

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ABSTRACT

The key to solving increasingly serious environmental problems is comprehensively to promote low carbon economy (LCE) development, while LCE development needs the conditions of particular system and capacity. This paper builds a cone model to focus on the analysis of these basic factors of low carbon technology innovation, carbon emissions right trading, carbon finance and low carbon policy to provide a theoretical basis for China's LCE practice. The results indicate that low carbon technology innovation is the basis for the LCE development, while carbon emissions right trading is the key to the LCE development. At the same time, the LCE development needs the corresponding conditions such as carbon finance and low carbon policies. Therefore, China should currently focus on these problems to promote the rapid development of LCE.

Keywords: Low Carbon Economy, Low Carbon Technology Innovation, Carbon Emissions Right Trading, Carbon Finance, Low Carbon Economy Policies
JEL Classifications: Q38, Q54, Q56

1. INTRODUCTION

How to promote low carbon economy (LCE) develop has become a major issue that all countries have been trying to solve with the frequent occurrence of global extreme climate. In fact, as the essence of LCE development is to take the transition of people's production and life way from currently industrial civilization with fossil energy to future ecological civilization oriented to clean energy, so it will result in a great change in socio-economic operation pattern and mechanism. However, because socio-economy has its inherent path dependency, it is necessary to create internal and external environmental conditions to adapt this change (Dou, 2015).

In recent decades, research literatures on LCE development are significantly increasing. Some studies focus on the innovation and R and D investment of low carbon technologies including low carbon energy technologies (Wiesenthal et al., 2012; Hong et al., 2015; Zafirakis et al., 2013; Chang et al., 2014; Kannan, 2009), carbon capture and storage technologies and others (Leung et al., 2014; Yuan and Lyon, 2012; Zhang et al., 2013; Koelbl et al., 2014). However, because of the complexity of low carbon technologies, the existing studies have not achieved satisfactory results as a whole. Other papers explore the status, the potential and influence, the roadmap and the relevant policy performance evaluation of LCE development (Wang et al., 2015; Bambawale and Sovacool, 2011; Liang and Wei, 2012; Sovacool and Dworkin, 2015; Knoope et al., 2013), but different studies come to different conclusions due to different research angle.

However, existing studies are not readily applied to China, for China is a major developing country in structural transition at the present stage, which determines the special conditions and contradiction of China's LCE development (Stua, 2013; Zhu et al., 2014). In fact, the basic pillars of LCE development are low carbon technology innovation and carbon trading, but they are all based on carbon finance and carbon policy. Therefore, it is necessary to create good system, mechanism and policy conditions for the comprehensive development of LCE at least at this stage. As LCE

development is a long-term and arduous systematic engineering, so only to create good conditions for its development and actively to promote it, the goal of LCE development can be realized finally for China (Zhang et al., 2014; Zhang et al., 2013).

Low carbon technology innovation, including technology adoption, diffusion, transfer, application, research and development, always plays a key role in LCE development. However, China is still in the infancy stage of the technology compared to developed countries. Therefore, China has to make a major innovation in low carbon technology (Shi and Lai 2010). Only to fully grasp key low carbon technologies and to fully hold strong self-innovation capability in LCE development, can China really take the lead in clean technology race and gain competitive advantage in new global LCE (Dou et al., 2013). The main problems in China's low carbon technology innovation are imperfect innovation system and lower innovation and promotion capacity. Therefore, China has to actively learn from the experience of developed countries (especially the European Union [EU]) and accelerate the improvement of low carbon technology innovation system and mechanism (Liu and Liang, 2013; Lai et al., 2012).

One of the most important factors to promote LCE development is carbon emissions right trading, while its basis is carbon credit and carbon market to provide basic finance and trading service for LCE development (Keohane, 2009; Wolfgang and Joseph, 2009). Because price and competition mechanism are fully used in carbon trading, it is a cost effective mechanism for controlling carbon emissions (Cui et al., 2014). In fact, as LCE is a new economy, so LCE development must be based on the associated markets. Especially, China has established pilot emissions trading systems and it has played an active role (Zhang et al., 2014). Therefore, how to improve the carbon trading market and system to fully play its role is one of the most important problems necessarily addressed in China's LCE development in the future.

Because LCE development in China is still in its infancy stage currently, the role of government's policy, development strategies, promotion and extension in LCE development is very significant (Wang and Chang, 2014a; Wang and Chang, 2014b). In fact, China, as a developing country, has always a contradiction between national environment protection, energy security and economic development. In such a case, central and local governments firstly have to make a scientific planning and strategic roadmap and to implement fair policies to boost initial pilot works (Hou et al., 2011; Wilson et al., 2011). Some complicated socio-economic and political factors in LCE development need the government to adjust and solve through law and policy instruments, too (Yi and Liu, 2015). In addition, because China is a government-led market economy country, the role of government in LCE development will be extensive and far-reaching (Dou, 2013a; Dou, 2013b).

Although China is actively taking various measures to promote LCE development to fundamentally solve increasingly serious environmental pollution problems, yet how to provide strong supports in system and mechanism innovation and capacity construction for LCE development is one of the major issues that has to be resolved in the future. It needs a systematic study of theory to provide a solid theoretical foundation for practice. However, the existing literatures in this field are scarce. To this end, the paper tries to overcome the downside of the existing studies in this field.

2. RESEARCH FRAMEWORK

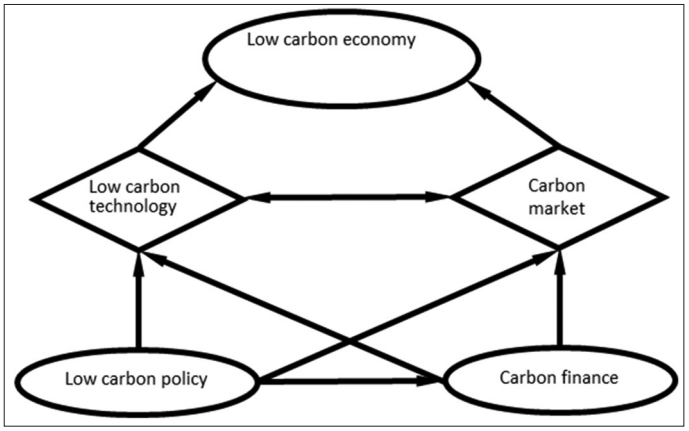
Chinese government pledged to cut carbon intensity 40-50% by 2020 in 2009. Again, China has now given the new commitment to cut carbon emissions 60-65% by 2030 to realize the decline of China's total carbon emissions by then. China has put forward a package of action plans on the climate conference in Paris in December 2015 to cope with climate change and emissions reduction. At the same time, China has been committed to strengthening cooperation with countries around the world in addressing climate change. However, because China is still a developing country, China needs to pay great efforts to achieve the promise of carbon emissions reduction targets.

The basis of LCE development is low carbon technology innovation and carbon emissions right trading. However, they, first of all, need a lot of money, restricting the low carbon action of the developing countries such as China. In addition, because China's market system and financial system is not perfect at the present stage, China also need to formulate and improve relevant policies and to establish corresponding service system to safeguard and promote them, as shown by cone model in Figure 1.

China should focus on the following problems at this stage.

a. Low carbon technology innovation. Low carbon technology innovation is the basis of LCE development. However, China's technological innovation system cannot fully meet the needs of LCE development at this stage. Because China currently practices government-oriented innovation system, the potentials of enterprise innovation have not been played to the greatest extent. However, the enterprise is the key agent of LCE development. Therefore, China should actively promote the low carbon technology innovation by enterprises in the future. It is one of the most important problems that China has to solve in the future.
b. Carbon market and carbon trade development. Carbon emissions right trading is not only one of the important

Figure 1: Low carbon economy operation mechanism



measures to promote energy-saving and emissions reduction, but also is an important means of the improvement of economic efficiency. The establishment of effective carbon emissions trading markets will help to promote energy-saving and emissions reduction in different regions and different levels. At present, China has started to practice carbon emissions right trading, but carbon trading mechanism is not still perfect. Therefore, China has to improve carbon market and carbon trading mechanism.

However, low carbon technology innovation and carbon trading are all based on associated carbon finance and incentive policies. The development of carbon finance is especially one of the most important factors that restrict the LCE development (Figure 1).

3. LOW CARBON TECHNOLOGY INNOVATION AND LCE DEVELOPMENT IN CHINA

3.1. Low Carbon Technology Innovation Strategy and Roadmap

LCE development is based on low carbon technologies. Advance in low carbon technology innovation directly determines the effectiveness or the success or failure of LCE development (Comello and Reichelstein, 2014). Low carbon technologies have many different types, for example, green energy technologies aiming at zero emissions, energy-saving and emissions reduction technologies aiming at low energy consumption and emissions cut, and carbon sink technologies aiming at carbon clearing, constituting a complex technical system.

Because innovation in low carbon technologies directly influences and determines the direction and property of future socio-economic development, it has become the focus of world technological innovation and the key areas that all countries compete for commanding heights. Therefore, China has to enhance low carbon technological innovation to the height of national strategy to obtain a favorable position in the new round of world technological innovation in the future (Heng and Liang, 2011).

China has to establish a medium-and long-term strategy of low carbon technology innovation and further to develop a comprehensively strategic planning and phased program of action to effectively promote the innovation due to the complexity of low carbon technology innovation. In fact, many countries have currently established the innovation strategy of low carbon technologies and formulated a concrete roadmap for action (Winskel et al., 2014). Obviously, low carbon technology innovation has become an indispensable part of national innovation strategies for almost all countries.

The significance to draw up and improve the innovation strategies of low carbon technologies is that it may direct technology innovation in future and scientifically guide to research institutions and enterprises to carry out the innovation activities to reduce or avoid blindness in low carbon technology innovation. In addition, to raise low carbon technology innovation to the height of national innovation strategies will help to integrate the innovative resources of entire country, which contribute to greatly improve the performance of low carbon technology innovation (Torvanger and Meadowcroft, 2011).

Although China's technological level is not very developed at the current stage, the conditions and abilities of technological innovation have been significantly improved since the reform and opening up. Especially in the fields of low carbon technologies, because many aspects are still at the initial infant stages of development, the gap between China and the developed countries is not great. China, in the fields of some low carbon technologies, has actually reached or closed to advanced levels in the world, which lay the conditions for low carbon technology innovation in the future.

However, China's national innovation system at this stage is not perfect and the state's capacity for independent innovation is still insufficient compared to developed countries, posing great challenges to low carbon technological innovation. Therefore, to establish and improve China's low carbon technology innovation strategy and roadmap as quickly as possible and comprehensively to carry out low carbon technology innovation activities, have a very important practical significance for speeding up LCE development (Roberto et al., 1998).

Although low carbon technology innovation strategy and roadmap of every nations in the world is not the same considering the innovative practices of low carbon technologies from abroad, all are almost concentrated on the fields of strategic energy technologies and on this basis to decide future research direction, long-term and intermediate technology roadmap and specific measures for implementation. Because energy is the basis of modern socio-economic development and the focus of climate change is also concentrated on energy, the core of low carbon technology innovation is the innovation of energy technologies (Winskel et al., 2014). Although China's situation is different from that of other countries, China's low carbon technology innovation strategy and roadmap is bound to focus on strategic energy technologies. Of course, the direction and innovation path of specific technology may differ from other countries. Especially, technology roadmap and specific action plan in the current stage should reflect China's national conditions and characteristics.

China has been practicing the innovation strategies of imitation and cooperation in a long time and lacks of independent innovation, resulting that it is always difficult to get rid of the situation of heavy dependence on foreign technologies. In view of this, China should fully implement independent innovation strategies to occupy a favorable position in the new round of international competition and to completely rid itself of passive situation controlled by other nations in key technologies (Dou et al., 2013). However, China has fully possessed the condition and capacity of independent innovation in some areas of low carbon technologies. The key issue is how to fully find potentials and effectively to apply them. It is an important problem that has to be solved in China's low carbon technology innovation in the future.

3.2. The Construction of Low Carbon Technology Innovation System

The innovation of low carbon technologies is related to government, universities and research institutions, enterprises and related intermediary organizations. Due to the complexity of low carbon technologies, any single innovative agent is difficult to independently complete a major innovation and it is necessary to be accomplished through the common collaboration of different innovative entities, especially to get support, financing and promotion from the state and government, which needs to establish an effective low carbon technology innovation system. Significance to establish low carbon technology innovation system is that it may give full play to the role and strength of the state, which contribute to the integration of the innovation resources of public and private innovation organization to accelerate the pace of low carbon technology innovation (Kennedy and Basu, 2013).

The core of innovation system construction for low carbon technology is to build an innovation network system covering main innovative agents such as government, universities and research institutions, enterprises and related intermediary organizations, and to give full play to the role of different innovation agents in technological innovation through certain scheme arrangement and incentive mechanism. In such an innovation system, government mainly plays the role of coordination, supporting, financing and promotion and relevant intermediary organizations play the role of linkage and bridge, while universities, research institutions and enterprises are the main bearers of low carbon technology innovation (Gosens et al., 2015). Only through linkages and interactions between these different innovation agents, new low carbon knowledge and technologies continually can be innovated and applied to achieve a desired performance.

Although universities, research institutions and enterprises are all main bearers of low carbon technology innovation from the perspective of innovative practice from different countries in the world, their roles in different countries are different. Low carbon technology innovation in some countries relies mainly on universities and research institutions, while the role of enterprises is to apply and promote the existing technologies. However, enterprises in other countries play a significant role, and most of applied technology innovations, in addition to a small number of foundation and key technologies, are achieved by enterprises (Hendry et al., 2010).

As enterprises directly face markets and are familiar with the products and technology demands of markets, so enterprises have particularly strong innovative power and willingness as well as a higher degree of standardization and commercialization of technologies relative to universities and research institutes. Of course, because low carbon technology innovation needs scientific and technological talents of high-quality and a lot of financial supports, not all firms have capacity to carry out R and D activities and only some of firms possessing strong research and financial strength have this condition (Ou and Zhang, 2010).

China's low carbon technology innovation mainly depends on universities and research institutions at present. Although the role of large- and medium-sized state-owned enterprises and private enterprises is becoming more and more prominent, their potentials have still been not played out fully. Therefore, it is necessary to learn from the advanced experience of foreign technology innovation to accelerate the establishment of China's modern low carbon technology innovation system of industry-academic-research collaboration. Enterprises play a leading role in this innovation system and universities and research institutions play a backing role, while intermediary organizations play a supporting role in the context of government's guidance and support.

In particular, China has to nurture and support the low carbon technology innovation activities of enterprises, and to take enterprises as the center of gravity to build low carbon technology innovation and support system. At the same time, it is still necessary from national and local government levels to actively support and fund universities and research institutions to engage in the research of basic and critical low carbon technologies, and constantly to enhance the capability of independent innovation to lay a foundation for low carbon technology innovation of enterprises and whole societies (Chesbrough, 2003).

3.3. Low Carbon Technology Innovation Mechanism

The innovation in low carbon technologies is achieved through specific innovative mechanism. Effective innovation mechanism will not only help to reduce the costs of the innovation, but also can greatly promote the innovation, dissemination and application of low carbon knowledge and technologies. Low carbon technology innovation mechanism is contained in economic operation mechanism under modern technical and economic conditions. However, because technological innovation has its internal rule, low carbon technology innovation mechanism will undoubtedly demonstrate its own characteristics and manifestations, too (Foxon and Pearson, 2008). Low carbon technology innovation may be achieved through either supply-driving innovation mechanism or demand-pull innovation mechanism or their combination considering innovative practice at home and abroad.

The inherent power of supply-driving innovation mechanism comes from the producer's pursuit of profit maximization. Enterprises in pursuit of profit maximization is bound to strive to cut production costs in increasingly fierce market competition according to the rules of competition on markets, but the key to cutting production costs is the innovation of products and technologies. Similarly, contestable enterprises are bound through the innovation and application of low carbon technologies to gain a competitive advantage in LCE development, too (Weber and Neuhoff, 2010).

In fact, the lifeblood of LCE, as a new economy, comes from associated technology innovation. Only the enterprises that have gained advantages in low carbon technology innovation can gain more interests in the new round of economic competition, and the constant innovation of enterprises in low carbon technologies is stimulated just through the constant pursuit of economic interests. Of course, it is possible to result in the lack of innovation power in the early stage of LCE development due to the immaturity of low carbon technologies and the large inputs of the development and application of low carbon technologies. In this case, it requires

government to take incentives to encourage enterprises to conduct the innovation of low carbon technologies (Baker et al., 2015).

Demand-pull innovation mechanism, different from supply-driving innovation mechanism, is to stimulate the innovation, dissemination and application of low carbon technologies through creating a market demand for low carbon technologies (Stechow et al., 2011). Enterprises lack the power of innovation and application in new technologies in many cases due to the role of economic and technological inertia. Especially, because low carbon technologies are different from traditional technologies, their innovation and application brings huge initial costs for enterprises. In this case, the state has to take compulsory measures to create the enterprises' demand for low carbon technologies, for example, to force enterprises to innovate and apply low carbon technologies through the control of the carbon emissions of enterprises or the implementation of mandatory green certification system, to encourage enterprises' demand for low carbon technologies through the subsidies for the development or use of new and renewable energy, and so forth. The increasing demand of markets for low carbon technologies will continually drive businesses and other related innovation entities to actively carry out low carbon technology innovation (Olmos et al., 2012).

Obviously, supply-driving innovation mechanism and demand-pull innovation mechanism has respectively their own advantages and deficiencies. In fact, both have mutual relation. On the one hand, the strong continued momentum of supply-driving innovation mechanism inevitably comes from the huge demand of markets for low carbon technologies. Especially, if there is no market demand for low carbon technologies for some professional research and development institutions of low carbon technologies, then they will lack the research and development power of low carbon technologies (Costantini et al., 2015).

On the other hand, the implementation of demand-pull innovation mechanism is based on the technological innovation capability of supply-driving innovation agents, which need to constantly improve the innovation capacity of low carbon technology innovation agents. Therefore, supply-driving innovation mechanism and demand-pull innovation mechanism can be organically combined to formulate and implement appropriate policies and measures to accelerate the pace and to improve the performance of low carbon technology innovation from the innovative policy point of view (Castillo and Linn, 2011).

4. CARBON EMISSIONS RIGHT TRADING AND LCE DEVELOPMENT IN CHINA

4.1. The Nature of Low Carbon Markets

The objective of trading on low carbon markets is carbon emissions rights. However, carbon emissions rights are artificial virtual assets, determining different nature of low carbon markets from general merchandise markets (Gao, 2006).

Carbon emissions right trading markets have currently two forms of normative markets and voluntary markets. Due to the constraints of mandatory regulation or agreement, normative markets are more active. However, due to limited emissions quota, their size is limited. In contrast, as voluntary markets are completely out of their own moral of economic agents spontaneously organized and carried out by relevant members of carbon emissions trading, so the markets are relatively free and may involve in a wider range. However, due to the lack of mandatory constraints, their transaction is not so active as normative markets (Zhang and Lu 2009).

Obviously, the efficiency of normative markets and voluntary markets is determined by carbon emissions right quotas and their initial allocation position, which is closely related to the responsibility of sovereign countries or corresponding organizations. In this sense, carbon emissions right trading markets have still certain political attributes (Wei et al., 2010).

4.2. Carbon Emissions Right Trading

At present, international carbon emissions right trading include two mechanisms of carbon emissions quota trading and carbon emissions reduction trading. Carbon quota trading mechanism is a kind of economic behavior about the allocation and transaction of carbon emissions right quotas based on the limited condition of total carbon emissions in specific area. In this trading mechanism, government first draws up an allocation scheme about carbon emissions rights based on emissions reduction technologies and potentials of different industries, and then assigns carbon emissions right quota through paid or unpaid manner to related economic agents, and finally supervises and administers the carbon emissions of related economic agents to follow assigned carbon emissions quota (Narayan and Sharma, 2015; Egenhofer, 2007).

However, the allocation of carbon emissions right quotas is based on historical economic situation in different regions, but the production and operation situation of economic agents is always in change. Therefore, the case of both the shortage of carbon emissions quotas for some economic agents and at the same time the surplus of carbon emissions quotas for other economic agents will inevitably occur. In this case, it needs a carbon trading market to adjust the supply and the demand. Obviously, carbon quota trading mechanism can compensate for the shortage of government allocation of carbon emissions rights, thereby increasing the effectiveness of carbon emissions right allocation (Eichner and Pethig, 2014). Relative to carbon tax, carbon quota trading mechanism will help to reduce inefficiency or non-efficient case caused by government's pricing, as it is completely in accordance with the laws of markets on carbon emissions right pricing, which is obviously beneficial to give full play to the role of market mechanism (Mustafa et al., 2004).

In addition to carbon quota trading mechanism, carbon emissions reduction trading based on project-specific emissions reduction is another trading mechanism. Among them, carbon emissions trading mechanisms designed by the Kyoto Protocol are the most typical, including emissions trading, joint implementation and clean development mechanism (CDM). Although the trading mechanism of carbon emissions reduction was launched in the

framework of carbon quota trading mechanism, it broke through the static nature of carbon emissions quota in trading mechanism, which make the transaction mechanism of carbon emissions reduction more flexible and has broader applicability to lay a foundation for international or regional environmental cooperation (Zheng and Liu, 2003a; Zheng and Liu, 2003b).

4.3. Carbon Emissions Trading Platform and its Construction

A sound trading platform is the basis of efficient operation of carbon market, including carbon trading system, carbon trading organizations, carbon trading venues, carbon trading facilities and related services, and so forth. Although there is still no integrated international carbon trading system, yet regional carbon trading system has shown a quick development from the perspective of globalization. Among them, the EU greenhouse gas emission trading scheme is the most typical and has currently become the engine of global carbon trading markets. In addition, the Chicago Climate Exchange, the Australia Greenhouse Gas Reduction Scheme and other regional carbon trading system have played an important role in their respective regional carbon trading, too (Xu and Lu, 2011).

Although global regional carbon trading system is gradually formed and developed, yet carbon trading is mainly made on regional or national market, resulting in serious market segmentation. In practice, the brisk transaction markets of carbon emissions rights are all most mandatory quota trading markets, and they have become the main bodies of carbon trading. In contrast, the transaction size of voluntary emissions reduction markets is relatively small, which is primarily related to its imperfect trading system design, non-regulation of trading standards and the lack of the innovation of carbon derivatives (Cui et al., 2014). In fact, because the determination and initial allocation of carbon emissions quota is difficultly set, the development of mandatory quota trading markets will inevitably be subject to some policy factors and have thereby great uncertainty.

However, voluntary emissions reduction markets have great flexibility. If an efficient trading platform and reasonable operating mechanism is built, then their market innovation power will undoubtedly exceed mandatory emissions reduction markets. Of course, the development of voluntary emissions reduction markets is directly subject to business pattern innovation and the development of carbon credits and they are endogenous in carbon trading system. It requires to organically integrate carbon trading platform construction and business pattern innovation with carbon credit development to really create a voluntary emissions trading system (Xing et al., 2010).

China unnecessarily bears international emissions reduction obligations at this stage according to the responsibility of developing country. However, China is one of the world's largest emitters of greenhouse gases (GHGs), while its GHG emissions reduction potentials are huge, too. Therefore, China's carbon trading shares are becoming greater and greater in CDM. However, because the pricing of carbon trading is controlled by the developed countries, the transaction interests of China in international carbon trading are limited. Therefore, China has to establish and develop its own carbon market and carbon trading system and gradually integrate it with international carbon trading system to get rid of such unfavorable situation (Fischer et al., 1998).

China has serious imbalance development between different regions, which creates good conditions for the development of domestic carbon markets considering real condition. Although economy in eastern regions is developed, yet environmental resources in these regions are limited. In contrast, economy in western regions is relatively backward, but environmental resources in these regions are richer. If an effective carbon trading market is established, then eastern regions may maintain the existing level of economic development by the purchase of environmental resources (carbon emissions rights) from western regions, which is not subject to a big impact caused by strict environmental resource management on economic development (Zhang et al., 2014). At the same time, western regions may also obtain economic benefits through the sale of environmental resources (carbon emissions rights) to east regions, and use the economic benefits to better improve environment and social welfare. Obviously, it is prior to that of single carbon tax or administrative management.

China should learn from the United States' experience of carbon market development from the perspective of global carbon trading. Firstly, China has to make a pilot start through building a mandatory carbon quota trading platform, as it can guide and promote the development of voluntary emissions reduction markets. At present, national and local governments have made clear planning on the goals and requirements of environment development in the 12th 5-year plan, which creates a favorable condition for the determination and initial allocation of total carbon emissions rights, and domestic carbon quota trading markets may be started in light of the planning (Ellerman, 2002).

5. DISCUSSION

5.1. Low Carbon Technology Innovation, Carbon Trading and Carbon Finance

As the research, development and application of low carbon technology requires a lot of capital support, so China has to establish the corresponding financial system. In fact, the fundamental purpose of carbon emissions right trading is to provide financial services for low carbon technology innovation and its application. Essentially, the basic objective and principle of carbon emissions right trading is to achieve the transfer of income and capitals between different economic agents through the creation and trading of virtual carbon emissions right assets. Therefore, carbon trading is essentially a sort of financial activities and a financial solution plan to address climate change.

Of course, carbon finance has its own characteristics compared with general financial activities. On the one hand, carbon finance is closely related to LCE activities and is to carry out financial activities around GHG emissions reduction. In fact, a variety of

financial instruments can be derived from carbon emissions right assets, and thus carbon trading can be organically integrated with carbon finance (Xie and Dou, 2015). In this sense, carbon finance becomes actually an important part of financial innovation.

On the other hand, the basis of carbon finance development is carbon markets. In turn, the development of carbon finance can contribute significantly to the development of carbon markets. Because carbon finance may provide a variety of financial instruments for carbon market transaction, this will greatly enhance the liquidity of carbon markets (Campiglio, 2016). Therefore, the development of carbon finance directly decides the development of carbon markets, and it is an important booster for the development of carbon markets.

However, the development of carbon finance involves two key issues. The first is how to form additional large capitals what the development of carbon market's needs. Apparently, it cannot be achieved through relying solely on the traditional way of capital formation. Secondly, traditional financial pattern clearly does not fit the needs of carbon market development, but to promote the transformation of traditional finance to carbon finance will involve the changes of financing concepts, policies, schemes, mechanisms, patterns and management structure (Dou, 2013b).

Certainly, China difficultly accomplishes such tasks in a short term only by the adaptive change of financial system and mechanism. Therefore, it poses a great challenge for the development of LCE and markets. In fact, the reason why carbon market and trading is underdeveloped at this stage is mainly the lack of sufficient funds (Mathews, 2008). Therefore, how to develop carbon credits and carbon finance, to establish and improve carbon financing scheme and mechanism and to build a developed carbon funds security system have become one of the most critical issues solved in the development of carbon markets in the future.

5.2. Carbon Credit Instrument and Carbon Financing

Carbon financing is achieved through a series of carbon credit instruments, while carbon credit instruments are essentially a sort of financial assets. Carbon credit instruments, as financial assets, have similarity with general financial instruments, and difference, too. The basis of carbon credit instruments is carbon emissions rights considering its financial attributes, while all other carbon credit instruments are derived from them (Howard et al., 2015). However, because carbon emissions rights themselves are the virtual assets of artificial creation, the size and scope of their transactions must be limited in the case that total quotas are restricted, affecting the liquidity and effectiveness of the markets.

The emergence of derivative carbon credit instruments such as the products of carbon futures and carbon options is inevitable. They can rapidly expand the size of transaction in a short period of time due to virtual property and high financial leverage function of derivative carbon credit instruments, which thereby greatly enhance the mobility and effectiveness of carbon markets. At the same time, the expansion of the transaction size of derivative carbon credit instruments can further enhance and improve the vitality and liquidity of the trading of underlying carbon credit instruments (carbon emissions rights). Therefore, the continuous creation and optimization of carbon credit instruments is a base to promote the development of carbon markets and to realize carbon financing (Wang, 2010).

The transaction agents of carbon credit instruments include the supply side, the demand side and the related intermediaries of carbon emissions rights. The supply side of carbon emissions rights is mainly the excess holders of carbon emissions rights, including the holders of unused carbon emissions quota, the implementers of emissions reduction projects, the holders of certificated emissions reduction, the financial institutions of holding carbon emissions trading balance and other holders of carbon emissions balance.

The demand of carbon emissions rights is mainly the contracting government and enterprises of fulfilling international emissions reduction obligations, the enterprises and social organizations of participating in voluntary emissions reduction mechanism and the purchasers involved in carbon emissions trading, and they are all the end-users of carbon emissions rights or the speculators on carbon markets. The related intermediaries include carbon financial institutions and carbon dealers, and they mainly provide information, transaction, finance and other services for carbon trading.

Specific carbon financing mechanisms have two different forms of indirect financing and direct financing. Indirect carbon financing mechanism are achieved through financial institutions (e.g., carbon banks, etc.). The providers of carbon credits save their carbon credits (e.g., the carbon reduction credits of carbon sinks and others) in related carbon financial institutions (banks) and obtain funds from them, while the demand sides of carbon credits may purchase necessary carbon credits (carbon emissions right quotas) from related carbon financial institutions (banks). The related financial institutions (banks) are here the operators of carbon financing as well as the takers of carbon credit risks. Such a financing mode clearly helps to reduce the costs and risks of carbon transaction and greatly increases the flexibility of carbon credits and carbon pricing (Esuola and Weersink, 2006).

The direct carbon financing mechanisms are achieved through carbon markets. The providers of carbon credits sell their excess carbon emissions right quotas on carbon markets, while the demand sides of carbon credits buys their carbon emissions right quotas through carbon markets. The supply side and the demand side of carbon credits make here direct relationship through carbon markets, and they are both the operators of carbon financing and the takers of carbon credit risks. Obviously, it is conducive to the formation of effective carbon trading markets in the role of competitive, price and risk mechanisms, thus contributing to better achieve carbon financing. Because the size and scope of carbon financing in direct carbon financing mechanisms is unrestricted compared to indirect carbon financing mechanisms, it helps to solve the problem of insufficient sources of carbon funds. Of course, the direct and the indirect carbon financing mechanisms have their pros and cons respectively, and they have in fact a complementary relationship each either (Sovacool, 2011).

5.3. Carbon Funds and its Run

Because both LCE development and carbon trading need a lot of capitals, the ability to obtain adequate funds becomes main obstacles restricting LCE development and carbon trading. Especially in the early stage of LCE development and carbon trading, the contradictions of the shortage of funds are more prominent. The first carbon funds were earlier resulted from special funds set up by international community to promote carbon emissions trading under the CDM. Since then, all governments and their agencies and some social organizations have began to establish the variety of carbon funds to promote the development of national or regional LCE (Nina and Julien, 2009).

Carbon funds have the characteristics of quasi-public goods by nature, as the basic roles of carbon funds are to help the countries or socio-economic organizations in the world to fulfill the responsibility for GHG emissions reduction to improve global climate and environment. Because the improvement in global climate can benefit all people, carbon funds in this sense are public goods. However, because the consequences of GHG emissions reductions caused by the economic behaviors of different socio-economic agents are different, their responsibilities for emissions reductions are different, too. Therefore, the allocation of carbon funds cannot be completely free of charge, and it is necessary to impose constraints on the different agents of responsibility based on the marginal costs of emissions and their marginal negative effects. In this sense, carbon funds have the nature of personal belongings, too (Lewis, 2010).

However, they play an important financing function in promoting LCE development and carbon trading no matter what type of carbon funds. Especially in the aspects of low carbon technology innovation and the start and promotion of low carbon projects, ordinary commercial and social capitals are reluctant to large-scale intervention in the fields due to the larger sizes and risks of investments. In this case, carbon funds will play an irreplaceable role.

At present, China has set up clean development funds, green development funds, new energy development funds and other low carbon funds. However, the funds of government investment and donor are still dominant. Moreover, investments from funds are more nonprofit operation, while market-oriented operation mechanism has not still formed, resulting in low efficiency, instability and uncertainty of low carbon funds. Therefore, China has to reform and improve the management and operation mechanism of China's low carbon funds through enterprise-oriented management mode and market-oriented operation mechanism.

6. POLICY RECOMMENDATIONS

6.1. Low Carbon-oriented Policy

The core of low carbon management philosophy and policy innovation is comprehensively to adopt the win-win idea of economic growth and environmental protection to promote socio-economic development. In practice, the focus of the innovation is to comprehensively promote energy saving, consumption cut and emissions reduction, vigorously to develop renewable and new energy industries, and greatly to nurture and develop carbon sink industries. Obviously, low carbon system and policy innovation can create such conditions for low carbon technology and industry innovation to make system and policy advantage into technological and industrial advantages further to be transformed into country's overall competitive advantage (Porter, 2002).

Basic policy elements to promote LCE development are carbon pricing and low carbon technology innovation (Cai, 2009). The essence of carbon price is to make dischargers to pay for their carbon emissions behavior, which contribute to the transition of people's consumption from high carbon to low carbon goods and services. Obviously, it is necessary to use price mechanism to promote LCE development.

Although the role of carbon price is significant, yet the base of LCE development is still the innovation of low carbon technologies. Only to achieve major low carbon technology innovation, can the targets of energy saving, consumption cut and emissions reduction be really achieved. Therefore, how to encourage and promote the innovation in low carbon technologies will be the focus of low carbon management and policy innovation. Especially in the early stage of low carbon technology innovation, the government's policy support is very important due to the great sizes and risks of investments (Torvanger and Meadowcroft, 2011).

6.2. Incentive and Exit Mechanism

The core of LCE development is how to effectively promote the transition of socio-economy from high carbon economy to LCE. Among them, one of the most key problems is how to promote the change of people's production and life style. However, it involves in two aspects of problems. On the one hand, as the production way and lifestyle of people formed has inherent inertia, so it is difficult to be consciously changed in a short term. On the other hand, because the production way and lifestyle of people formed under particular socio-economic conditions has been in a relatively mature and stable state, to try to change it will increase the costs of action. Unless there is the role of external forces, otherwise relevant actors have not benefit motive to change their inherent production way and lifestyle. Therefore, it is necessary for government to design and implement relevant incentive and mandatory exit mechanisms in the stage that the natural evolution mechanism and the internal power mechanism of LCE development have been not yet formed (Foxon et al., 2005; Muench et al., 2014).

Low carbon incentives include the two aspects of the materials and the spirits. The core of material incentives is to give economic incentives such as investment preferences, tax cuts, financial subsidies and others for the low carbonization action of producers and consumers to compensate for additional costs in low carbon action. In fact, because LCE contains huge potentials of economic benefits, both producers and consumers have the desire of consciously taking part in LCE action. The key to problem is that, to change the existing economic behaviors will inevitably face greater risks and pay more additional costs in the case that LCE

and technology is not yet developed, and thus it is necessary to give appropriate economic incentives (Qiang et al., 2014).

The role of material incentives is after all limited. Therefore, spiritual incentives are still necessary. The core of spiritual incentives is to give some honors to actors that consciously practice low carbon production and lifestyle to make low carbon actors to appreciate the social value of their own behaviors thereby to stimulate their inherent potentials to consciously practice. Another side of spiritual incentives is education, guidance, demonstration and propaganda role of the government. The propaganda and education can develop people's low carbon behavior awareness and value viewpoint, which is fundamental guarantee for LCE development. The guidance and demonstration of the government can make people to truly appreciate and feel the economic and ecological value of low carbon behaviors. All these will help to stimulate the enthusiasm of people consciously to take low carbon action (Roach, 2013).

The incentives are sometimes difficult to function effectively under the driving of economic interests. Therefore, the state has to implement necessary mandatory exit mechanisms, for example, to implement mandatory exit for great energy consumption and heavily polluting industries, to restrict the sale and use of high energy consumption and low energy efficiency products, to prohibit the building and use of construction and transport facilities beyond energy-saving and environmental standards, to prohibit the use of disposable daily necessities, to implement mandatory energy certification system, and so forth. Only to implement mandatory exit mechanisms in some industries and fields can achieve significant results for LCE development (Burer and Wustenhagen, 2009; Wiser, 2000).

6.3. Scientific Evaluation and Assessment System

One of basic measures of promoting LCE development is to establish a set of scientific and comprehensive monitoring, evaluation and assessment system. It may not only scientifically evaluate and assess the performance of local governments, producers and consumers in LCE action, but also is conducive to fully bring their enthusiasm and creativity into play.

The assessment and evaluation of LCE development is related to the two levels of the macro and the micro. On macro level, it is mainly systematic and scientific examination and evaluation of central government on LCE development of local governments and different departments. Current economic appraisal system and scheme is mainly carried out around economic growth, but environmental protection is paid less attention, which often causes the contradiction that more emphasizes on economic growth but neglects environmental protection (Chau et al., 2015). The fundamental purpose of LCE development is to organically integrate economic growth with environmental protection to achieve harmonious development between nature, economy and society, which needs to establish and perfect green gross domestic product (GDP) accounting system and scheme.

China has begun to carry out green GDP accounting system, but its effects are not obvious because of the lack of a comprehensive scientific examination and evaluation system and specific organization and implementation system. Therefore, China has to establish a scientific and comprehensive green GDP accounting system as soon as possible to give full play to its role in promoting LCE development.

The producers and consumers are the object of examination and evaluation on micro level. In LCE development, the low carbon action of producers and consumers is not only essential, but also directly determines the success or not and the effectiveness of LCE development. Therefore, to establish and improve statistic, monitoring, evaluation and assessment and examination system for low carbon economic action of producers and consumers is very necessary (Ahlroth et al., 2011). Scientific appraisal system is conducive to the norms and monitoring of the government for low carbon economic action of producers and consumers as well as to incentives for producers and consumers to consciously take part in LCE action. In addition, scientific evaluation system is also the basis of country's formulation and implementation of relevant laws and regulations.

Some countries have actively engaged in the carbon footprint assessment of businesses and individuals focused on product carbon footprint, and have initially established carbon footprint assessment and accounting standards and standardized methods (Zhao et al., 2005; Plassmann, 2010). Practice has proved that, carbon footprint assessment and accounting has played a very important role in the low carbon action of producers and consumers.

China's carbon footprint assessment is still currently at the preliminary stage of pilot, and carbon footprint assessment system and scheme has not yet officially formed, which makes that the incentives and regulations of government on the low carbon action of producers and consumers lose the scientific basis and standards. At the same time, it is not conducive to the establishment of the green image of businesses and individuals in China. Therefore, China has to accelerate such work (Chen, 2010).

6.4. Ecological Compensation Mechanism

Basic driving force for LCE development comes from the pursuit of the economic interests of low carbon economic agents. Therefore, to build an effective ecological compensation mechanism has a great significance for promoting the sustainable development of LCE. All socio-economic activities are driven by interests under the conditions of modern market economy, and LCE development is no exception, too. Only to give appropriate economic benefit compensation for the actors actively involved in LCE can fully bring their initiative and creativity of active participation in low carbon economic activity into play (Home et al., 2014). The essence of ecological compensation mechanism is to internalize external costs to achieve the redistribution of interests compared to legal, administrative and other economic means, and it thereby can more effectively use economic leverage to regulate the economic behaviors of different low carbon economic activities.

Ecological compensation mechanisms include two different forms of administration-oriented and market-oriented compensation

mechanisms. The core of administration-oriented compensation mechanism is the establishment of ecological compensation funds to use the funds to subsidize or compensate for LCE actors. Obviously, the implementation of administration-oriented compensation mechanism will face two basic problems.

The first is the ability to raise sufficient funds. Ecological compensation funds mainly come from fiscal special funds, carbon tax (environmental tax) income and social donations, which determine the limited scale of ecological compensation funds. However, because LCE development is related to entire socio-economic activities, the demand for compensation funds is enormous, making it difficultly to avoid asymmetry contradiction between the supply and the demand of ecological compensation funds.

The second is the reasonable allocation of ecological compensation funds. In theory, it is possible to make a compensation for them on the basis of the marginal low carbon contribution of low carbon economic agents, but it is actually difficult to be achieved. As marginal low carbon contribution is difficult to be accurately measured and at the same time there may be imperfect information and irrational rent-seeking behaviors, so the role of administration-oriented compensation mechanisms is limited. At least, it is difficult to be continuously promoted and applied on a large scale (Gong et al., 2012; Liu, 2008).

Different from administration-oriented compensation mechanism, market-oriented compensation mechanism is achieved through the allocation and trading of carbon emissions rights. Specifically speaking, the state will make a mandatory requirement for the maximum carbon emissions quantity of different regions based on the reality of socio-economic development in different regions, but the regions that carbon emissions are beyond carbon emissions quotas may purchase carbon emissions rights from the holders (other regions) of excess carbon emissions quotas (Feng et al., 2015). The essence of such carbon emissions trading is the economic compensation of high emissions regions for low emissions regions. Obviously, market-oriented compensation mechanism is more to use the function of markets to avoid the drawbacks of administrative means.

However, market-oriented compensation mechanism has many constraints, too. The first is the reasonable determination and distribution of carbon emissions right quotas in different regions. If this problem is not properly handled, it will not only affect the equity of inter-district development, but also seriously affect the enthusiasm and economic efficiency of different regional economy development, which is the focus of international low carbon game, too. Secondly, carbon emissions right trading requires a developed carbon trading market and carbon financial service system, but it is difficult to be fully equipped in a short term (Clot et al., 2015).

In a word, administration-oriented compensation mechanism and market-oriented compensation mechanism has their own advantages and shortcomings, respectively. Generally, because conditions are not good in the early stages of LCE development, the role of administration-oriented compensation mechanism may be more prominent. However, when LCE has developed to a more mature phase, the role of market-oriented compensation mechanism should be more played.

7. CONCLUSIONS

The cone model of LCE development indicates that the basis of LCE development is low carbon technology innovation and carbon emissions right trading, but they are all based on the associated carbon finance and incentive policies.

The carbon trading object is carbon emissions rights, while its purpose is to allocate low carbon economic resources through carbon price to promote related economic agents to actively carry out LCE. However, carbon trading needs an efficient trading platform including carbon trading system, organization and institution, venues, facilities and related services and so forth, which needs to establish a comprehensive carbon-market system and an effective carbon market operation mechanism.

The key to LCE development is low carbon technology innovation. If there is no innovation in low carbon technologies, it is impossible to truly realize large-scale energy saving and emissions reduction. The innovation of low carbon technologies is related to governments, universities and research institutions, enterprises and related intermediary organizations. Due to the complexity of low carbon technologies, any single innovation agent is difficult to independently complete a major low carbon technology innovation. Therefore, it is necessary to achieve it by common collaboration of different innovative agents. Especially, China has to establish a dynamic innovation system of low carbon technology giving full play to the role and strength of the state embodied in a national strategy.

All LCE activities including low carbon technology innovation and carbon trading need a financial support. In fact, carbon trading is essentially a sort of financial activities and is just a financial solution to address climate change. In addition, both low carbon investment and technology innovation cannot be separated from the support of carbon finance. Therefore, whether China can build a developed carbon financial system and a perfect carbon finance mechanism is directly related to the success or the failure of LCE development in China.

The essence of LCE development is to achieve a series of innovative activities of transition from high carbon to LCE, but it is likely to produce many contradictions in the process, which need to build an effective government management and adjustment system and mechanism. The core of the state's policy and management is to achieve the innovation of low carbon management philosophy and policy around two basic policies of carbon emissions right pricing and low carbon technology innovation. Among them, the most fundamental problem is how to build a comprehensive incentive and exit mechanism, scientific examination and evaluation mechanism and effective ecological compensation mechanism.

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