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REVIEW PAPER

Evolutionary pattern, operation mechanism and policy orientation of low carbon economy development

X. Dou*

School of Economics and Management, Southwest Jiaotong University, Chengdu, P.R. China

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ABSTRACT: The essence of low carbon economy development is a continuous evolution and innovation process of socio-economic system from traditional high carbon economy to new sustainable green low carbon economy to achieve a sustainable dynamic balance and benign interactive development of various elements between society, economy and natural ecosystem. At the current stage, China's socio-economy is showing the feature of "three high" (high energy consumption, high emissions and high pollution). In this case, quickly to promote the development of green low carbon economy is necessary and urgent. This research indicates that, low carbon economy development is achieved by micro-economic agents such as households, businesses and social intermediary organizations through Government's guidance and the role of market mechanism. In low carbon economy development, the state (government) is a leader and markets are core, while economic agents (e.g., households, businesses and social intermediary organizations) are basis. For this reason, it is necessary to build an effective cleaner development and incentive-compatible policy system oriented to end-users.

KEYWORDS: *Cleaner development; Low carbon economy (LCE); Evolutionary pattern; Incentive-compatible policy; Oriented to end-users; Operation mechanism*

INTRODUCTION

How to promote low carbon economy (LCE) development has been one of the hottest issues addressed by the circles of theory and practice. Because basic requirement for LCE development is fully to change the current pattern of economic development, it is assuredly related to many issues such as economic, social, legal and political factors, which needs to make corresponding change in existing socio-economic system to create a favorable external environment condition for LCE development (Dou, 2013a). Especially in the early stage of low carbon economy development, because self-organization evolution mechanism and system for LCE development has not yet formed, in this case to inject into development factors from the outside of system is more important, which requires to bring the guidance, support and promotion role of government into full play (Dou, 2013b; Dou and Cui, 2016).

However, how to give full play to the role of the state is a severe challenge and there are still many problems and uncertainties. Because LCE development is mainly done through market under the conditions of modern market economy, it needs to fairly handle the relationship between government, market and other economic agents. Apparently, only to create a good environment and mechanism for low carbon economy, can it help better to coordinate the relationship between the three and to play their role effectively, but it depends on the state's development belief, strategy and policy. Only to adhere to the belief and strategy of socio-economic development in harmony with nature, can it guarantee any socio-economic behaviors of government, markets and other economic agents not to excessively deviate from the track of LCE

*Corresponding Author Email: *douxiangsheng@tsinghua.org.cn*
Tel.: +0861 5198 016 680

development, which is conducive to improving the relationship between the three (Mulugetta and Urban, 2010).

The economic behaviors of economic agents such as households (consumers), businesses (producers) and social intermediary organizations are crucial for LCE development. Only when economic actors consciously take the action of a low carbon economy, can LCE development obtain substantial results, which need to build an appropriate incentive and restraint mechanism to guide, promote and regulate it. And in all incentive and restraint mechanisms, the mechanism of market competition and price adjustment is the most basic, while the incentive and restraint mechanism of the state's policy is only to make up for the inadequacy of market function (Dou, 2015a). Therefore, LCE development must follow certain evolutionary logic and pattern. Only by doing so, the costs of LCE development can be minimized.

Because there are a lot of uncertainties in reality, it is necessary carefully to select and build the pattern and mechanism of LCE development to create the conditions for quick transition of socio-economy from high carbon to low carbon economy (Li and Wang, 2012). On the whole, it is necessary first to build a cleaner development pattern and mechanism, which is the core issues addressed necessarily for LCE development. In specific implementation, it is necessary to establish an incentive-compatible propulsion mechanism and system oriented to end-users.

China's economy has been in a state of extensive growth, and the problems of resources waste and environmental pollution have been very prominent. Because Chinese socio-economy is in the stage of structural transformation, to promote LCE development is necessary as well as feasible. To this end, this paper will combine China's reality to explore above issues. The remaining of paper is organized as follows. The second part reviews the role of the state in the early stage of LCE development. The third part explores the evolutionary pattern and mechanism of LCE development. Reduction, recycling and cleaner development will be examined in the fourth part. The fifth part discusses incentive-compatible propulsion policy oriented to end-users. The final is conclusions.

This study has been carried out in China's Realistic Context in 2011.

The role of the state in the early stage of LCE development: A literature review

In essence, the core of LCE development is to realize the transition of existing economic structure and growth mode based on dirty power (fossil energy) to sustainable green economy. Therefore, the role of the state, especially in the early stage of LCE development, is very important. In fact, national short- to long-term goals, plans and policies on LCE development send signals of credibility and reliability for investors and practitioners (the enterprise and the public) to guide countries down a path towards LCE growth (United Nations ESCAP, 2011). Generally, if the state implements functional interventions designed to remedy market failures rather than selective interventions, then it is likely to be more effective or less inefficient (Brown, 1993). As China is still a government-led market economy currently, so the role of the state in LCE development is more important. Especially in the early stages that natural evolution system and market and social operation mechanism for China's LCE development has not yet formed, the businesses, social intermediary organizations and individuals can not consciously take a LCE action due to the inertia of economic agents for profit. In this case, the role of the state is crucial (Dou, 2013a).

The European Union in LCE development has been at the forefront of other countries, which are connected with the aid and support of the state. Just because of the full implementation of state aid rules, it promoted the EU's LCE development. Obviously, the macro strategy and aid of the state has played a decisive role from the EU experience of LCE development. As Bütikofer (2013) said that,

"*Market forces left to themselves will not drive the economic and societal transformation we need. Governments urgently have to set framework conditions that steer competition and innovation in a new, green and sustainable direction.*"

As China is a great developing country facing structural transformation and industrial upgrading, so she needs more the state aid to provide an excellent opportunity for promoting a transformation to a low carbon and green economy (Jean, 1995). China formulated and implemented the planning of the "China's Policies and Actions for Addressing Climate Change (2013)" in 2013 (NDRC, 2013), and just in its guidance and restraint, China has achieved remarkable results. In fact, because LCE development means major

increases in investment, rapid innovation and the creation of new markets, the central and local governments will give full play to one's talent in the future (Dou, 2013b).

The role of the state in LCE development is reflected in the carbon emissions right trading platform construction, reasonable carbon emissions right quota allocation and the coordination of relevant interests, too (Xie and Dou, 2015). As all LCE activities of government, households, businesses and social intermediary organizations are around markets to carry out, so markets are bridge and link that various types of economic agents interrelate as well as an important competitive workplace that economic agents pursue their own maximal interests. Therefore, how to establish and improve carbon trading market has become one of the most key problems that the governments have to address (Schwartz, 2010; Barbier, 2011).

The transition from traditional high carbon to low carbon economy will inevitably increase the costs of firm's production and management due to the constraints of rapid innovation and structural transformation. Therefore, if there are not the intervention and support of government, firms will lack the power for low carbon production. As for social intermediary organizations, at the early stage, all types of social intermediary organizations required by LCE development have not still formed actually, which requires the government to take appropriate policies and measures to cultivate and develop them, too (Yuan *et al*., 2011).

Moreover, because consumption viewpoints and habits for consumers are difficultly changed in a short run and consumption facilities are inadequate in the transition of consumption structure, it leads to consumers difficultly in a short run to consciously carry out low carbon consumption, which requires government to take a variety of mandatory or incentive measures to regulate and guide consumers to low carbon-oriented consumption (Xing *et al*., 2010).

In a word, the state's roles have many, including the direct and indirect effects of government on LCE agents. Of course, although the state has a leading role in a LCE development, yet it does not mean that the role of the state (government) is omnipotent. On the contrary, the government is only a complement of market. Only the fields of low carbon economy that the market mechanism difficultly functions need government's intervention. It needs properly to manipulate the relationship between government's leading role and market-oriented operation (Joshi *et al*., 2015).

The evolution patterns and structural transformation of LCE development

Consumption-oriented evolution

The essence of LCE development is a continuous evolution and innovation process of socio-economic system from traditional high carbon economy to new low carbon economy to achieve sustainable dynamic development and positive interaction of material, energy, information and value flows between society, economy and natural ecosystem (Foxon, 2011; Xu and Lu, 2011). Generally, LCE development follows the evolutionary logic and patterns from consumption to production or from production to consumption. Although their direction, path, mechanism and power are different each other, yet both have their own advantages and disadvantages, respectively.

As people's consumption is the ultimate goal of any socio-economic activities and all economic activities are almost around consumption to work, so LCE development should follow the evolution logic and pattern from consumption to production with no exception, too. In fact, from consumption side to practice low carbon economy can get better results. Especially in today's China, the phenomenon of wasteful consumption is very serious, resulting in increasing environmental pressures related to consumption. Therefore, vigorously to promote the consumption-oriented evolution of LCE development not only helps to form a better consumption pattern, but also has great development potentials (Brizga *et al*., 2014).

Production-oriented evolution

However, some of productive sectors are at the extremity of consumption link, thus consumers have only weak direct impact on them. In this case, to follow the evolutionary logic and pattern from producers to consumers, that is, directly from production side to practice LCE activities may get better effects. In addition, for some of productive fields with high energy consumption and heavy pollution, only to take direct low carbon action from production side, can it obtain better effects (Yang, 2008).

In fact, the key to LCE development is in production side, for production sectors are the key fields of the resource and energy consumption and the pollutant

emissions. Further, low carbon-oriented production can create its own associated consumption. Therefore, only production sectors to achieve a low carbon development, can the goals of low carbon economy be really realized. Moreover, the low carbon-oriented evolution of production sectors is related to the three levels of enterprise, industry and society (Xie and Kong, 2005). Among them, enterprise is the most basic unit of production, so in the entire link of low carbon production, the low carbon production of the enterprise is in a basic and key position.

Low carbon production is a complete change against traditional production mode and reflects the principles of cleaner production and environment protection in all aspects, for example, product development and design, raw material selection, production process and technology, energy use, waste treatment, and so forth. By doing so, it not only itself realizes the goals of cleaner production and energy saving, but also avoids the transfer of pollutants in different environmental media. Further, enterprise is one of the main bodies of significant technological innovation, too. Especially, the development and utility of applied low carbon technologies are mainly done by enterprises. Therefore, the development and utility of enterprise's low carbon technologies may drive the development and utility of low carbon technologies in whole industries and societies, which is one of the most effective ways of low carbon technology innovation (Hou *et al*., 2011; Shi and Lai, 2013).

Industries-oriented evolution and eco-industrial parks

In low carbon production, although enterprises are in a basic and key position, yet for a single enterprise, as it is only a link in whole industrial chains, so enterprise's performance is closely related to whole industries. Moreover, although industries are a multi-level network system formed by interrelated different enterprises including the lateral and the longitudinal association, yet LCE development for industries is not a simple sum of enterprise's LCE development, and performance from low carbon industries is often higher than the sum of the performance from all enterprises. In fact, enterprise's low carbon development often produces some external effects, but low carbon industries may internalize these external effects (Wang and Chang, 2014). Therefore, some negative external effects will be covered, while positive external effects are freed as much as possible. Obviously, the performance of low carbon industries is undoubtedly higher than the sum of performance from all corresponding enterprises (Zhang and Wang, 2014). In practice, many countries have actively promoted the development of eco-industrial parks to promote industrial low carbon-oriented development. Because eco-industrial parks are the industrial communities of efficiently sharing resources (e.g., resources, energy, information and public facilities, etc.) and take the coordination development of economic, environmental and social functions as the goal, an efficient product and waste chain in this symbiotic network system is formed, which creates the conditions for reduction, reuse and re-resource development.

Since the late 1990s, China has begun to build ecological demonstration industrial park zone. Some eco-industrial parks (e.g., the Suzhou Industrial Park, and the Tianjin Economic and Technological Development Zone, etc.) has got good economic, ecological and social benefits. Different from the traditional mode of design-production-use-waste emissions, eco-industrial parks take the circulation economy mode of the recovery-reuse-design-production imitating the material circulation of natural ecological system to form an industrial symbiosis combination in resource sharing and by-product exchange between different enterprises to change the waste generated from upstream production into raw materials for downstream production to realize the optimization allocation and utility of resources. Because eco-industrial parks focus on internal ecological chain and network construction, they may maximize resource utilization and minimize waste emissions from the source to ensure the realization of regional cleaner production to a large extent (Bai *et al*., 2014). Therefore, China should give full play to the role of eco-industrial parks in LCE development in the future.

Emerging low carbon industry development

On a social level, it is necessary to vigorously develop emerging low carbon industries, for example, new and renewable energy, energy saving and environmental protection, electric cars, new medicine, new materials, biology breeding, information industry, etc., for they have huge market promise, low energy and resource consumption, more employment opportunity, high comprehensive benefit and eco-

friendly characteristics. Of course, in economic function and nature, emerging low carbon industries are actually endogenous to traditional industrial chains and are a further extension and deepening of traditional industry chains, only as increasingly developed market and a higher level of technology lead them to become ... *et al*., 2014). However, once they become relatively independent industries, then their role in industrial development cannot be replaced by other enterprises and traditional industries, as they can engage in LCE activities across enterprise, industry and trade, which can promote the low carbon-oriented development of whole socio-economic system. In fact, the role of emerging industries in LCE development is more and more important, which has become an indispensable field of ecology-oriented development of industries. Therefore, it is still necessary to make great efforts to cultivate and develop emerging low carbon industries to create conditions for the full realization of the final goals.

Low carbon-oriented transformation of traditional industries

In China's existing industries, traditional industries have a large proportion and significant position. Traditional industries are labor-intensive and manufacturing-based industries, such as steel, coal, electric power, building, automobile, textile, light industry, shipbuilding and others. Because traditional industries have the characteristics of high energy consumption, high inputs and high emissions, it is necessary to accelerate the transformation and upgrading of traditional industries to low carbon and green industries to give full play to their potentials of energy saving, consumption cut and emission reduction (Zhou *et al*., 2013).

A task of top priority for China is currently to drop out backward industries, as they are the biggest beasts of energy and resource consumption and pollution emissions. Especially in some heavy industry cities and backward areas, they are the main causes resulting in energy shortage and environmental pollution. Of course, for the traditional industries that may not be eliminated, it is necessary to speed up their upgrading and transformation (Li and Wang, 2012). In fact, from the perspective of enterprises, although the upgrading and transformation of traditional industries are related to financial and technical problems, yet as these activities can greatly enhance the competitiveness of enterprises, so relatively the costs of their implementation are lower and thereby it is one of the most effective ways to promote LCE development in a short time.

The driving force of LCE development

Driving force to promote low carbon action of economic agents come from internal and external motivation. Among them, inherent motivation is driven by profit maximization, while external motivation is generated from the dependence of LCE agents on specific LCE environment (especially adaptive competition). However, in the early stage of LCE development, because specific environment has not yet been formed, driving force comes mainly from inherent motivation (Foxon, 2011; Colvin *et al*., 2014). Therefore, in the early stage that the self-evolutionary system of low carbon economy has not been yet built, the guide and incentives from government is very important and is an important power source and starter to promote LCE development. Once self-evolutionary system and mechanism for LCE and specific environment have been formed, then LCE agents must adapt to collective evolution behaviors in a particular environment, thereby promoting an adaptive change of LCE agents, and furthermore this adaptive change has a continuously driving force, which provides stable power for LCE development. Obviously, the selection of a power source and start mechanism for LCE development is very important, and it is the basic conditions of continuous evolution of a low carbon economy based on inherent path (Geels, 2005; Rodrigo *et al*., 2015).

The core of LCE development: Reduction, recycling and cleaner development

Cleaner development pattern and its key roadmap

Ultimate goal of LCE development is fully to realize cleaner development, but it is a complex thing, for it is related to many aspects of production, circulation and consumption. As Fig. 1 shows that production, circulation and consumption need all to consume resources and energy, and at the same time they produce waste, too. Therefore, cleaner development involves four factors.

a. The front end of socio-economic activities—the reduction of resources and energy inputs and consumption;

b. The middle end of socio-economic activities—the reduction of waste generation;

c. The last end of socio-economic activities—the recycling and recovery of waste for reuse;

d. The last end of socio-economic activities—the harmless processing of waste for emissions (Fig. 1).

Obviously, only in each link of production, circulation and consumption to realize cleaner operation, can the goal be finally achieved. However, traditional environmental governance mainly focuses on the end of pollution, that is, to control and administer waste and pollutants at the last end of socio-economic activities, which results in the transfer of waste (especially pollutants) in different environmental media and is not able to fundamentally solve environmental problems (Qian and Qian, 1998; Wang *et al*., 2014).

Different from traditional environmental governance, cleaner development emphasizes prevention, control and governance on pollutions in the whole process from the front to the last end. In the front end, namely at the stage of inputs and use of resource and energy, it is through technological innovation, structural optimization, and management innovation to minimize the consumption of resources and energy, that is, to

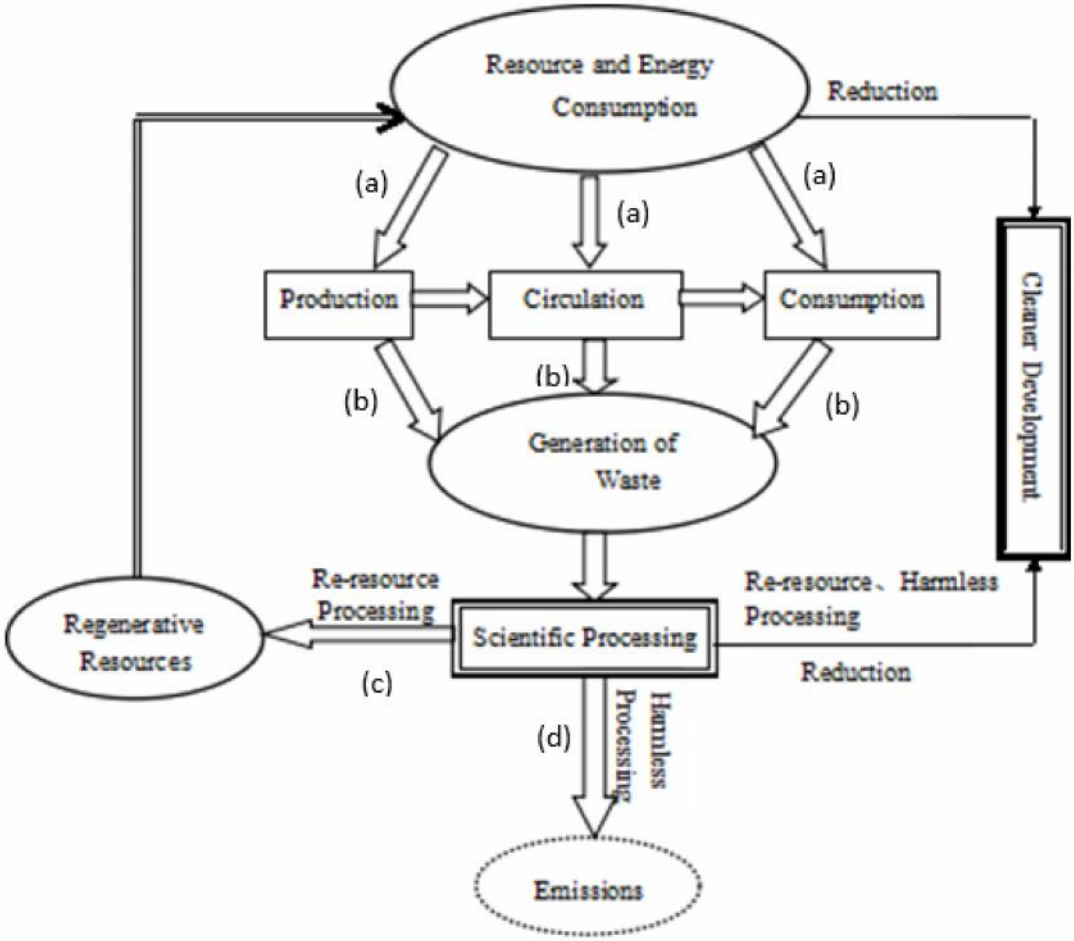

Fig. 1: Cleaner development pattern and its key roadmap

realize the run of reduction (or minus-materialization) to prevent and control pollution from the source. It not only can greatly reduce the generation of waste and the treatment costs of pollution at the end, but also can significantly improve the use efficiency and economic benefits of resources and energy (Zhang, 2006).

Furthermore, at the last end, namely at the stage of generation and processing of waste, it is through scientific treatment for waste to reduce the emissions of pollutants. On the one hand, to take waste resources to be recycled and reused through the recycling technique of re-resources can not only improve the utilization rate of resources, but also achieve emissions reduction from the waste. In addition, to make pollutants that can no longer become resources into the emissions of harmless substances through harmless processing technology may effectively avoid their pollution to environment. Obviously, only through prevention, control and governance in the whole process, can cleaner development be truly achieved (Liu and Bai, 2014).

The reduction of inputs: Minus-materialization

As can be seen from Fig. 1 that, the key factors of cleaner development are reduction (minus-materialization) and recycling (re-resource). The nature of reduction is minus-materialization, namely, less materialistic inputs and less consumption, including the reduction of material inputs (the reduction and minimum of resource and energy inputs) as well as the reduction of waste emissions (the reduction and minimum of generation and emissions of waste). The reduction of resource and energy inputs not only can greatly cut the effective demand of socio-economic activities for resources and energy and improve the efficiency of resources, but also is beneficial to prevent and control the generation and transfers of pollutants in different environmental media from the source, which has the function at the root of a problem (Hu *et al*., 2011).

Furthermore, the reduction of generation and emissions of waste is further deepened based on the reduction of resource and energy inputs. Because of the inevitability of waste generation in social and economic activities, through controlling and treating at the last end again, it can ensure the minimum waste emissions to thereby eliminate or mitigate their harm to the environment. Obviously, the reduction (minus-materialization) has a key function in cleaner development.

The recycling and recovery of waste: Re-resource

Different from the reduction of inputs and emissions of material resources, re-resource (recycling) focuses on the renewability of material resources to transform potential physical resources (e.g., waste, etc.) that cannot be originally used into available material resources. It not only increases the range and effective supply of resources, but also helps at the end of socio-economic activities to realize emissions cut, as reduction at the stage of waste emissions is realized mainly through the recycling and use of renewable resources in waste (Mo *et al*., 2009). In this sense, re-resource (recycling) is actually an integral part of all links of reduction, and they have an inner relation.

In addition, although to make harmless treatment of waste (essentially, the reduction of pollutant emissions) can not directly increase real available resources, but because harmless emissions have no longer destructive effects on nature and ecological environment or significantly mitigated damage, so it indirectly increases sustainable natural and environmental resources, which is actually an indirect re-resource (recycling) process (Dou, 2015b). Obviously, both reduction (minus-materialization) and re-resource (recycling) are the essential elements of cleaner development, and they determine together the property, process and result of cleaner development.

Cleaner production

In cleaner development, production link is especially important for the consumption of resources and energy and the generation of waste. At the same time, the cleaner status of production link has a direct impact on cleaner development of distribution and consumption link. If the problems of pollution caused by production process, for example, the use of toxic and hazardous raw materials, the lag of production technology and craft, the extensive internal management of business and the discharge of waste without being processed, etc., cannot be solved, then it will not only bring about great difficulties for follow-up control and treatment on pollution, but also cause potential harm on related environmental media, which is unable to be fundamentally eliminated in follow-up link and stage. Therefore, it is necessary to prevent and control pollution from the production stage, that is, to

implement cleaner production. The essence of cleaner production is to maximize the use of raw materials, to maximize energy savings and to minimize the generation of waste in the production process. Simply speaking, cleaner production means cleaner resources and energy, cleaner production process and cleaner products, and it can be realized just through comprehensive process control in entire production and life cycle of products (Song, 2008).

In practice, cleaner production involves three levels of business, industry and society. At the level of business it is to realize cleaner manufacturing, and at the level of industry it is to realize the ecology-oriented development of industry, while at the level of society it is to realize recycling and processing and cleaner re-manufacturing for waste caused with the use of products (Xie and Kong, 2005). Obviously, cleaner production is an inevitable choice for the industry to take a road of sustainable development, and it is one of the most effective ways to achieve the strategic objectives of sustainable development. At present, China has promulgated and implemented the Cleaner Production Promotion Law, which provides a legal guarantee for the full implementation of cleaner production. If this law can be well implemented, then it will certainly contribute greatly to promote coordinated development between economy and environment. Therefore, it is necessary to adopt relevant policies and measures to comprehensively promote it (Taylor, 2006).

Cleaner consumption

Cleaner development in consumption link is another important aspect. This stems from the fact that consumption is an ultimate goal for all socio-economic activities of people. However in consumption, people not only consume a lot of material goods and energy, but will also produce a lot of waste. Especially in the prevalence of convenience and extravagant consumption in today's society, consumption fields have undoubtedly huge potentials on energy saving and emissions cut. If government can guide people to shift to a healthy and civilized cleaner consumption characterized with low carbon from convenient and luxury consumption characterized with high carbon, then it not only can greatly reduce the consumption of materials and energy, but also is conducive to waste and pollutant emissions reduction from life. Therefore, in cleaner development, cleaner consumption is another aspect of having a decisive influence that is secondary only to cleaner production (Jiang *et al*., 2013).

From the perspective of energy saving and emission reduction, cleaner consumption comes from the various aspects of people's daily life. In fact, as long as people enhance the awareness of energy saving and emissions reduction and change irrational life habits and lifestyle, e.g., to select energy-saving electronic products, to pay attention to saving water and electricity, to abstain from the use of disposable supplies, to consume primary foods as much as possible, to select public transport or to use small exhaust cars or to go on foot on people's daily travel, to select energy-saving housing, to minimize life garbage, etc., then the targets of energy saving and emissions reduction may be effectively achieved (Xing *et al*., 2010).

The key is that, due to consumer's inertia, inherent consumption customs and ways for people in the short term are difficultly changed, which needs to adopt corresponding policies and measures to actively guide consumers to change their inherent consumption attitudes and patterns (Hornik *et al*., 1995; Tsiliyannis, 2007). It must be pointed out that, in the link of consumption, the most urgent problem solved necessarily is solid waste treatment in the residential neighborhoods of the city, for it has become one of the most important factors affecting the health of residents in many cities. Therefore, to implement a systematic and sustainable treatment taking re-resource (recycling), harmless processing and reduction (minus-materialization) as principle for municipal solid wastes, has become one of the most important problems to be urgently addressed in the cleaner development of consumption link at this stage (Shekdar, 2009).

Cleaner circulation

Different from cleaner development in production and consumption link, because circulation is only a bridge and linkage to connect production and consumption, cleaner development in circulation link has its own particular property. On the one hand, in circulation link, besides that the manufacturing and maintenance of transport means by itself need to consume resources and energy as well as to consume energy and emit harmful substances during transport, as it is itself neither to create nor to consume products and the use cycle of transport tools itself is also generally longer, so its immediate impact on the

environment is limited (Xu and Lin, 2015; Yan and Crookes, 2010).

On the other hand, to facilitate storage, transportation and circulation, people often need to treat the transported goods with packaging and reinforcement processing, and a large amount of waste are produced in this link, which may make a bad impact on environment. Therefore, cleaner development in circulation is an important aspect that cannot be ignored, too. The key to cleaner development in circulation link is to optimize the supply chain of logistics, to develop the low-power consumption and high-capacity means of transport to improve the efficiency of logistics and to decrease the phenomena of cross transport and inefficient transport as far as possible. In addition, to implement strict emissions standards for transport means and to remanufacture discarded transport equipment is one of important ways to achieve cleaner and sustainable development of circulation link, too (Xu *et al*., 2004).

Incentive compatibility policy oriented to end-users

Policy orientation and its core

To accelerate traditional socio-economic transition to low carbon economy has become society-wide consensus, but how to effectively promote its development is still a difficulty problem that government and society need to make great efforts to explore and resolve, for it directly determines the success or failure of LCE development. In fact, it involves at least two key issues. The first is the choice of starting source. It is not only directly related to whether the driving force is enough strong, but also directly related to the costs and effects of LCE development. The second is an effective incentive mechanism and its function. It is not only directly related to external environmental conditions of LCE development, but also directly related to the formation and its effectiveness of driving force for sustainable LCE development in socio-economic system (Dou, 2013a; 2013b).

In practice, it is a more effective way of low-carbonization propulsion through affecting end-users' choice and taking products as a link and sensor to guide the whole community in each link of production and consumption to comprehensively participate in low carbon economy. To take end-users as an orientation is based on market mechanism oriented to consumers' demand, while to take the products as a link and sensor can maximally radiate and affect almost all areas of socio-economy and all economic agents. Therefore, it can not only through market-oriented means to stimulate and promote LCE development, but also help to produce maximum incentive compatibility effects in a certain institutional environment (Wilson *et al*., 2015; Miara *et al*., 2014).

The core of taking end-users as an orientation to promote LCE development is to create a revealed signal and corresponding transmission mechanism, and its purpose is to help end-users to identify and select low carbon products and services for their use and consumption, and to take it as an orientation to stimulate the production of low carbon products and the supply of low carbon services to achieve the low carbon-oriented development of whole socio-economy. As for the construction of specific revealed signal and transmission mechanism, it has two aspects of product and energy. The former can be done through the establishment of low carbon product certification system, while the latter can be achieved through the establishment of energy conservation certification system. Essentially, there exists an intrinsic linkage as well as a certain degree of relative independence between them.

Low carbon product certification system

Considering the international trend of LCE development, certification system for low carbon products has been proven to be more feasible and effective way for greenhouse gas (GHG) emissions reduction. Its advantage is to take products as link and orientation and make the assessment and accounting for GHG emissions from entire life cycle process of products, such as the gain of raw materials, production, packaging, storage and transportation, distribution and sale, utility, discarding, processing and so forth. At the same time, to grant the products with lower GHG emissions than national standards in whole life cycle for a low carbon sign may guide buyers and consumers more to purchase and use such products to achieve the purpose of GHG emissions reduction (Pei *et al*., 2010). Obviously, the implementation of low carbon product certification system is not only conducive to promoting LCE development and the achievement of energy conservation goals, but also as a market-oriented means it is more conducive to inspiring related economic agents consciously to practice low carbon economy, which is an inevitable choice for promoting LCE development.

The basis and prerequisite for the implementation of low carbon product certification system is an assessment and accounting for carbon footprint (GHG emissions) from the whole life cycle of products. Because only to take a scientific and systematic evaluation and accounting for GHG emissions directly or indirectly from products and services throughout whole life cycle, can it provide a scientific basis and the norm for quantitative criteria for government, enterprises and public to understand and manage GHG emissions. In this sense, the system of low carbon product certification and its related carbon labeling is only a form and means that the government manages GHG emissions, while its implementation is fully established on the basis of assessment and accounting for carbon footprint.

Obviously, assessment and accounting for carbon footprint are a deeper level problem. In fact, assessment and accounting for carbon footprint has currently become one of the most important measures to promote LCE development. Many countries or regions have launched the experimental work, and introduced a series of programs and standards of assessment and accounting for carbon footprint (Plassmann *et al*., 2010; Kenny and Gray, 2009). For example, the EU's eco-label system awards the green product recognized by the EU to encourage consumers to purchase for the eco-label to promote the green production of manufacturers. At the same time, allowing traders and retailers applies their own brand of merchandise for the eco-label. Although it is a voluntary eco-label and payment system, it is better to promote the LCE development in the EU (The EU, 2014).

At present, China has also started the experimental work of carbon footprint assessment, but has not still established a comprehensive assessment and accounting system (Hong and Li, 2013). To this end, it is necessary to strengthen international cooperation, actively to take part in the draft of international classification rules and standards of carbon footprint of products, to establish and improve the assessment system of carbon footprint and the database of carbon emissions factors, and actively to strive for initiative rights and to seize high ground to create conditions for comprehensively promoting LCE development and enhancing the green image of enterprise and nation (Zhang and Xu, 2011).

Implementation of low carbon product certification system involves in the stipulation of relevant threshold. Specifically, it has two aspects. The first is a national standard in terms of GHG emissions. Its basic requirement is not only able to maximize the role of energy saving and emissions reduction, but also to do that enterprises and public have ability to consciously carry out the activities in accordance with applicable standards. The second is the national standard of GHG emissions in accordance with international standards. Only to set up assessment and certification standard being consistent with international practice, can it reduce potential green trade barriers and enhance international competitiveness of products from China, and at the same time help to prevent foreign pollution industries and products to be transferred to domestic to ensure sustainable development of China's foreign trade, too (Chen, 2010). The former belongs to the advance issue of low carbon product certification, while the latter belongs to internationalization issue.

Obviously, the issue of advances is relatively easy to be solved and can be done through the implementation of top-runner standard system. In contrast, internationalization issue is more complex, for there is still a gap between China and developed countries in economic and technical level at this stage, which determines that China's environmental protection threshold is difficult to satisfy the standards of developed countries currently. Furthermore, it likely leads to all kinds of barriers set by developed countries against China, which generate certain pressure and difficulty for China's opening up. How to resolve this contradiction is a serious problem that China must think and solve in the future in a long period of time. This is one of important factors restricting effective implementation of low carbon product certification and low carbon labeling system, too.

Energy conservation certification system

Besides above-mentioned low carbon product certification and low carbon labeling system, another revealed signal and its transmission mechanism are the identification system of energy saving certification and energy efficiency standard. Different from low carbon product certification and carbon labeling system focusing on reducing material consumptions and carbon emissions, it is mainly through reducing energy consumption and improving energy efficiency to cut GHG emissions and protect resources and environment. However, although both have the same role in energy saving and consumption cut and emissions reduction,

but it has relatively many advantages, for example, the low costs of implementation, the wide range of function, the significance of energy saving and environmental protection effect, and so forth (Shi, 2014).

As energy saving certification and labeling system for energy efficiency standard is related to many fields, such as household appliances and other living facilities, office equipment, transportation and communication tools, industrial and commercial equipment and public infrastructure, etc., and at the same time it is closely linked with end-users, so vigorously to promote energy conservation certification and the labeling system of energy efficiency standard will not only help to radically reduce energy consumption and improve energy efficiency, but also have relatively lower costs of implementation and monitoring (Cao *et al*., 2010). Just for this reason, energy conservation certification and the labeling system of energy efficiency standard have currently been popularized and applied in many countries. Moreover, some developed countries such as the Japan, the United States, the European Union and the others through the implementation of this system have significantly reduced the energy consumption of per unit GDP (Vine and Hamrin, 2008).

However, currently as low-power consumption products in China have not still popularization, so China's energy saving potentials is huge. If China can actively learn from foreign successful experience and implement energy conservation certification and the labeling system of energy efficiency standard deeply and extensively, then it is bound to help to greatly encourage the development and use of efficient energy-saving technologies and products, to effectively promote the improvement of energy efficiency levels and to promote the realization of energy conservation and emissions reduction targets.

At present, China has practiced the certification system on green lighting products, household refrigerator, vehicles and some industrial products with high energy consumption. However, there are still more improved and perfected spaces on many aspects, such as the regulatory construction of energy efficiency certification and labeling, the establishment, implementation and management of energy efficiency standard, the related international cooperation, and so forth. Therefore, it is necessary to create a better market environment and condition to fully play their role.

CONCLUSION

LCE development is achieved by micro-economic agents through government's guidance and the role of market mechanism. In this socio-economic system, government is a leader and markets are core, while households, businesses, and social intermediary organizations are basis. Households, businesses, social intermediary organizations, government and markets through specific operation mechanism interweave together to form a complex network organization system, and LCE development is achieved through such a complex network organization system with specific evolution and operation law.

The essence of LCE development is a continuous evolution and innovation process of socio-economic system from traditional high carbon economy to new low carbon economy. From the perspective of evolutionary logic and pattern, LCE development follows evolutionary logic and pattern from consumption to production or from production to consumption. The focus of LCE development is primarily production sectors, as production sectors are the key areas of both resource and energy consumption and pollutant emissions. In addition, low carbon production can still create its own low carbon consumption, too. Considering the evolution process, LCE development must follow by evolution process and way from energy saving, consumption cut and emission reduction to the development of emerging low carbon industries. As for the driving force of LCE development, driving force to promote low carbon action of economic agents has two aspects of both internal and external motivation.

The norms of the success or not of LCE development are whether cleaner development can be fully realized. Because cleaner development is the prevention, control and treatment of the whole process on various socio-economic links such as production, circulation and consumption taking reduction (minus-materialization) and re-resource (recycling) as a core, it may fundamentally solve environmental issues. To this end, it is necessary

to take end-users as an orientation and products as a link and through affecting public's consumption choices to guide whole society to carry out LCE activities in every links of production and consumption in a wide range, which is the low-carbonization propulsion mode of economy with an incentive compatibility nature.

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CONFLICT OF INTEREST

The author declares that there are no conflicts of interest regarding the publication of this manuscript.

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