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Integrated Evaluation of

Circular Economy Development Level of Qinghai Province

Policy Advice on Promoting the Circular Economy in Qinghai Province

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Abstract

The research project fully draws on related national and international experiences regarding evaluation of circular economy development, and adequately takes various factors affecting the development of circular economy into consideration, in accordance with implications, development objectives and principles of circular economy. The study has established an evaluation indicators system for circular economy in terms of economic, social and resource-environmental systems, on the basis of analyzing system structure and level structure, and combing the design principles of evaluation indicators system of circular economy. Furthermore, it carries out horizontal and vertical comparisons of the developments of circular economy among 13 provinces or municipalities, including Qinghai, over the period from 2010 to 2014, using the improved method of principal component analysis, namely, method of global Principal Component Analysis (PCA), based on the comprehensive comparison of various types of evaluation methods. The horizontal comparison allows for an objective and accurate understanding of the current development status of Qinghai circular economy within the PRC, while the vertical comparison can not only allow for a good understanding of changing trends of the circular economy development in Qinghai, but also sheds some light on the changing trends of circular economy development of different provinces or municipalities. Based on the above, people can gain some insights into the present development situation of circular economy in Qinghai as well as China from the perspective of development trends. The research project mainly focuses on the following aspects:

1. **Developing Evaluation Indicators.** The research project has constructed a four-level indicators system regarding integrated evaluation of circular economy development in terms of economic, social and resource-environmental systems. The structure consists of four levels, namely, objective level, system level, criterion level and indicator level. The whole indicators system comprises of 32 indicators, with respective interpretations.

2. **Identifying Evaluation Methods and Developing Evaluation Models.** International and national scholars mainly adopt such evaluation methods as entropy evaluation method, data envelopment analysis (DEA), integrated fuzzy evaluation method and principal component analysis (PCA) for conducting evaluation of regional circular economy development. Based on the advantages and disadvantages of the above methods and the characteristics of circular economy development in China, and in order, the research project has adopted the global PCA method to carry out an integrated evaluation of the circular economy development level in Qinghai. Such a method was aimed to avoid the disadvantages of the currently available evaluation methods, to improve the scientific rationality and convenience of evaluation models and to obtain well-rounded, scientific and accurate evaluation results. On such basis, it has developed a number of concrete evaluation models.

3. **Empirical Analysis.** The research project carries out an objective and accurate evaluation of the development level of circular economy in Qinghai Province through both the horizontal and vertical comparisons. *Horizontal Comparison*: in 2015, 13 provinces or municipalities like Tianjin, Liaoning, Shanghai, Jiangsu, Anhui, Shandong, Hunan, Guangdong, Chongqing, Sichuan, Shanxi, Gansu and Qinghai went through review and evaluation and were declared as national circular economy

pilot units. Therefore, the horizontal comparison can allow for a more in-depth understanding of the current development level of circular economy of Qinghai within the context of whole China. *Vertical comparison*: The vertical time series dynamic comparison of the development levels of circular economy in 13 provinces or municipalities, during the period from 2010 to 2014, can allow for an understanding of the changing trends of circular economy development in Qinghai as well as comparing historic trends of circular economy development in other provinces or municipalities, thus providing an insight into the current development level of circular economy in Qinghai as well as in China from the angle of development trends.

4. **Conclusions.** *Horizontal Comparison*: There has been considerable discrepancy in development level of circular economy between Qinghai Province and nationwide priority areas. Such discrepancy is a result of constraints in terms of technological level, economic level and social development capacities. *Vertical Comparison*: The development of circular economy in Qinghai is characterized with rapid growth and remarkable effects on energy conservation and emission reduction, generally showing positive development momentum. Therefore, it must be clearly recognized that it is an arduous task to construct national circular economy pilot zones in Qinghai Province. In order to fulfill the mandate of the central government to develop circular economy, it is important to firmly establish a new norm of economic, intensive and recycling use of resources through applying five development concepts such as innovation, coordination, green, opening and sharing. It is essential to develop the circular economy by centering on increasing resource outputs of the whole society as well as innovations in science & technology, production models and industrial activities. In addition, it makes perfect sense to stimulate new motivations through system and institutional innovations to speed up Qinghai’s transformation towards a green and circular society, and lay a solid foundation for the full establishment of a Xiao Kang society and becoming a leader in the national circular economy development by 2020.

Contents

Preface

Since the "Twelfth Five-Year Plan", the Qinghai Provincial Government have adopted circular economy as a strategic approach to addressing shortcomings of industrial structure, taking full advantage of local strengths based on the provincial realities, enabling development of circular economy to be a major means of transforming economic development. It hinges on the central government's requirements of building national pilot zones of circular economy development, and is aimed to improve the quality and benefits of economic development. During the "Twelfth Five-Year Plan", the industrial structure had become more optimal, with the 10 key strategic industries becoming increasingly prominent, the industrial chain of circular economy beginning to emerge, and some new and featured industries such as renewable energy, advanced materials and biotech products showing rapid growth in Qinghai Province. The "Thirteenth Five-Year Plan" period is a key transitional stage, where the circular economy in Qinghai is proceeding with the ice-breaking process. According to the *Action Plan of the Construction of National Pilot Zones of Circular Economy in Qinghai*, by 2020, the industrial structure in Qinghai will be more rational, the integrated utilization and output of resources will be remarkably enhanced, and the scale of circular economy will be greatly expanded to become the dominant development model, thus achieving the ultimate success of building national pilot zones of circular economy in Qinghai.

For the purpose of exploring an effective approach to circular economy development, and achieving the goal of establishing national pilot zones of circular economy during the period of the "Thirteenth Five-Year Plan", it is essential to carry out an adequate analysis of the current status of the circular economy development in Qinghai Province, which can provide a broad direction for the further development of the circular economy in China. Towards this end, this report conducts a comprehensive evaluation, which allows for an accurate understanding of the current level and the future development trend of the circular economy in Qinghai Province; and it also provides a theoretical and empirical basis for the future government planning and development policy initiatives.

Chapter I Implications of Circular Economy Development and Analysis of Its Influencing Factors

I. Implications of Circular Economy Development

1. Concepts of Circular Economy Development

Globally, with the constant increase of the world population, resource-based energy that is essential to maintain economic and social development has been hardly well-sustained; the ecological environment been overloaded, thus the human beings are faced with enormous development challenges. In a sense, the traditional economic operation model has an increasing number of problems in the promotion and realization of the sustainable development, even to the vulnerable point, so the human development calls for creating a new economic growth approach as the great support. Therefore, since the 1970s, countries all over the world has pondered over traditional robbing resource use, linear growth model and their own productive and living behaviors and begun to explore how to transform economic development models so as to achieve new development. Simultaneously, governments in different countries and international institutions also have included the issue in their respective agendas.

The idea of circular economy emerged in the 1960s. In 1966, American economist Portin developed the concept of circular economy based on the theory of spaceship [1]. The proposal has aroused the widespread attention of the whole world and the consensus of all walks of life. The circular economy is a new economic development model that covers from the bankruptcy of the idea of conventional development to the harmony between human and nature and includes the coordination, harmony and synergic development between the whole human society and nature, thus representing an innovative orientation away from the traditional economic operation system. In 1972, the Rome Club, a trans-boundary civic academic organization consisting of scientists, economists and entrepreneurs from many countries, published a study entitled the *Limits to Growth*, in which *Chapter 3: Per Capita Resource Use* exclusively states the issue of resource recycle, pointing out that natural resources, especially rare natural resources, will restrict the development and reach the limits to growth by eventually bringing its development to a stop. The study has set off the first warning signal to the whole world: "If global population, industrialization, pollution, food production and resource consumption go continues at the current rate, the limits to growth on the planet- the Earth will happen someday in the next 100 years." It was considered the first report to have examined the relationships between economic growth, and population, natural resources, ecological environment and scientific & technological advancement. In 1983, the World Environment & Development Commission of the United Nations began to examine the issue of "No Limit" sustainable development, and in 1987, it issued a study report named "Our Common Future", in which the Chapter of Management of Public Resources is devoted to the discussion of how to achieve the effective and efficient use, regeneration and recycle of resources by means of management and the proposal that the issue of sustainable development can be addressed by the nature pattern of ecological system and the recycling use of natural resources. Till this time, the concept of circular economy came into existence, drawing the attention of the international community.

The concept of circular economy also enlightened an international economic study on resources and the environment starting from in the late 1960s. The study held that the essence of circular economy is to make use of the least resource consumption and the minimum environmental price to achieve the maximum development benefits, in the sense that it is firstly a new development idea, secondly a new model of economic growth and finally a new model of pollution management.

The *Law of Promotion of Circular Economy of the People's Republic of China* defines circular economy as "It is a generic term that includes such activities as volume reduction, reuse and resource-orientation conducted in the process of production, circulation and consumption." The Environment and Integrated Resource Utilization Division of the National Development and Reform Commission develops a definition that "Circular economy is an economic growth model, meaning that recycling use and saving of resources is used to achieve the maximum development benefits at the expense of the least resource consumption and the minimum environmental pollution, with its principles of amount reduction, regeneration and resource-orientation, its core of recycling use and saving of resources, that is, the maximum increase of efficiency of resource use, and its results of the saving of resources, the enhancement of benefits and the reduction of environmental pollutions." Therefore, it can be seen that recycle development is a strategy that integrates economic development, resource saving and environmental protection.

2. Implications of Circular Economy Development

At present, academics have varying opinions regarding implications of circular economy. Experts and scholars, applied researchers in different disciplines or fields have provided delineations as to recycle development depending on their own professional fields and different perspectives of understanding and research[2]. Here are representative points of view as follows:

1) Circular Economy in a Broad Sense

Circular economy, which covers 3 important aspects, namely, economic development, social advancement and ecological environment, is aimed at pursuing a state of the ideal combination of the three systems. In a broad sense, it is a range of activities of social production and reproduction centering on effective and efficient resource use and environment-friendliness, with the objective of obtaining the maximum economic and social benefits and achieving the harmonious development between human and nature at the least expense of resources and the environment. Therefore, extensive circular economy is more than the creation and development of circular economy systems within an industrial system and a social system, but more importantly, it is the integration of such factors as population, resources, environment and society into the theoretical system of circular economy. In other words, the broad one contends that within a big system of people, natural resources and science & technology, the constant improvement of efficiency of resources use in the overall process of resources input, enterprise production, products consumption and disposal allows for shifting the traditional economic development relying on resource consumption increase to the new economic development depending on ecological resources recycle so as to achieve the harmonious development between human and nature as well as the organic integration of resource efficiency and environment-friendliness that constitute the core part of circular economy.

2) Circular Economy in a Narrow Sense

In a narrow sense, circular economy mainly refers to the amount reduction and resource orientation of wastes, that is, the development of economy through such activities of social production and reproduction as reuse and recycle of wastes, equal to “garbage economy” or “wastes economy”. In general, economy is relative to a given activity of social production and corresponding to a particular industry. For instance, the concept of circular economy that originated in Germany and Japan is the opposite of the concept of “venous” industry. The venous industry refers to an industry built on the resource orientation of wastes as opposed to artery industry depending on the explorative utilization of natural resources. Based on the national realities, the popularization and promotion of circular economy within China shall not fall into its narrow sense category.

3) Circular Economy in Terms of Ecology and Environment Protection

The idea of circular economy developed from ecological balance and environmental protection, thus many definitions of circular economy focus on the implication of ecology and environmental protection. Researchers hold that circular economy is, in essence, an ecological economy, an epoch environment protection development model and an innovative economic development approach embodied by the recycling use of mass and energy, which allow for low emission, even zero emission of pollutants, the integration of clean production, comprehensive resource use, ecological design and sustainable consumption, the realization of recycling use of mass and energy in the process of economic development, and the harmonious integration of economic system into the system of nature ecology, thus achieving an ecological economy.

4) Circular Economy from the Perspective of Economics

The development of circular economy is the result of pondering over the conventional economic development model. As a new economic process and growth approach, circular economy is an innovative economic form rather than a single economic element. It is reckoned with resource saving and environmental restriction, having the major characteristic of recycling use of resources with low consumption and low emission and high efficiency. It uses resources in a friendly way to enable all raw materials and energy to be reasonably and efficiently utilized in the process of constant economic recycle. It also encourages human production activities to be emerged into the natural recycle process of harmonious coexistence of ecology, economy and society, environmental protection and economic development to be organically combined, thus enabling the control of impacts of human economic activities over the natural environment to the minimum extent. There is another proposal that there exists the same identity between circular economy and market economy, both of which are in conformity with the regular pattern of economic development.

5) Circular Economy from the Aspect of Technical Economics

From the aspect of technical economics, one scholar views circular economy as a paradigm revolution that reflects the essence of its economic form. As Professor Fen

Zhijun points out in its paper entitled *Circular economy is a Great Strategy*, circular economy is a paradigm revolution, which is embodied in the four aspects as follows: firstly, ecological ethics make a shift from human centralism to life center ethic and ecological center ethic. Ecological ethic of end treatment is human-centered, while the ethic emphasized by circular economy holds the ecological transformation in the fields of production and consumption, recognizing the existence of ecological position and the right of respecting nature. Secondly, the issue of ecological threshold receives extensive attention. Circular economy emphasizes that the rational use of natural capital within the threshold range is a capacity of self-organization for effectively protecting ecological system based on the right of respecting nature. Thirdly, the role of natural capital is re-recognized. Circular economy classifies the natural capital as the most important capital form – the largest capital reserve in the human society, thus arguing that the improvement of the productive efficiency of resources is the biggest capital reserve for the human society, the key to addressing environment issues. Finally, it is contended that circular economy is a transformation from the shallow ecological idea to the deep ecological idea.

6) Circular Economy from the Angle of Production Mode

Circular economy changes the traditional economy, a linear economy of single movement from resource to products to wastes, thus achieving a model of naturally harmonious recycling production from resources to products and regenerative resources. As Mr. Zou Shenwen put it, circular economy, designed to pursue the maximum utilization of resources and the minimum pollutants emission, is an important economic development strategy that integrates clean production, comprehensive resource use, ecological design and sustainable consumption. Mr. Jiang jinqi holds the view that circular economy means relying on human intelligence and scientific and technological advancement arising from the intelligence as well as clean (with no public hazard) production means to take resources and wastes as a raw material of recycling use for repetitive use many times, without no or less pollution in the process of production.

II. Roles of Circular Economy Development

1. Objectives of Circular Economy Development

In accordance with the fundamental theory of circular economy, circular economy development has the highest goal of achieving the constant advance of economic development of human society under the condition of sustainable ecology, a general objective of circular economy development. It can be further divided into 3 specific objectives, namely, dematerializing, realizing equitable intergeneration use of environmental resources and meeting overall development and welfare growth of human beings. [3].

1) Dematerializing

One of the specific objectives of recycle ecology development is to realize the socio-economic development with the restricted resource environment as well as dematerialization through the significant improvement of ecological efficiency. Circular economy is a bio-mimetic economic model by which, according to the design idea of nature-centeredness, every product in a closed- loop production system ends up by harmlessly returning to the ecological system as a nutrient like compound wastes, alternatively, it changes into a raw material for the production of another product. "In nature, when the consumption of one species becomes a kind of food of another species, there may be occasional chaos and imbalance, but the ecosphere can normally adjust and restore by itself. Thus, a recycle and recovery economy should operate in a life cycle from cradle to cradle rather than in the process from cradle to tomb. In other words, every product or side product is designed to have its next form before it is produced, thus its designer shall have in mind the future application of the product and how to avoid its subsequent wastes at the outset. In such a way, there will not be dangerous and biologically useless wastes." Our requirement for corporate production model shall be making a shift from the center of labor-resulted productive efficiency to the center of resource-resulted productive efficiency (increasing resource utilization rate), that is, dematerialization promoted by circular economy.

2) Realizing Equitable Intergeneration Use of Environmental Resources

Another specific objective of circular economy development is to achieve the sustainable development of ecology. In 1987, *Our Common Future* made the first vivid elaboration on the definition of "sustainable development", saying that intergeneration equity constitutes the key content of sustainable development, and that circular economy development puts particular emphasis on equitable intergeneration use of environmental resources. Currently, the growth of economic system is badly restricted by the resource-based environment, posing a threat to the continuity and abundance of natural resources. As social divisions become increasingly definite and science & technology increasingly sophisticated, the rough production and living styles have constantly created new records of scale and extent of material metabolism between human and nature. If it goes unchanged, equitable intergeneration use of natural environment resources will be seriously affected, thus showing the unsustainable growth.

3) Meeting Overall Development and Welfare Growth Objectives of Human Beings

Within the perspective of circular economy aimed at achieving the human sustainable development, its highest pursuit is to enhance the continuity of overall wellbeing of human being. With the further development of circular economy, in the model of dematerialization, the development path of technology has shifted from end treatment to the improvement of ecological efficiency; "wise products system" has enabled "service-based economy" to become a corporate catchword, thus making the human society move from the current material society to the functional society; business has become an ecological practice, for healthy business greatly improves natural productivity to reduce the use of natural resources, thus transforming the society with great resource consumption into a society with no (less) resource consumption.

2. Principles of Circular Economy Development

Since the introduction of relevant theories regarding circular economy into the PRC, there has never been discontinued discussion over the formulation of principles of circular economy development catering to national realities in the academic circle of China. In the initial stage of theoretical discussion and theoretical promotion, it is not uncommon to find that the academic circle uses “volume reduction, reuse, recycling (resource-orientation), (3R principles) as major principles of circular economy development in China. With the experimentation and extension of circular economy in China, researchers have obtained a better understanding of circular economy. Additionally, with the constant exploration of theory and practice, scholars have developed additional principles such as “Rethinking”, “Recovery”, “Reorganization”, “Remanufacture” and “No-Harm”, which provide a beneficial supplementation to the traditional 3R principles, thus playing a positive role in the development of circular economy in the PRC.

1) Principle of Volume Reduction

The principle of volume reduction requires that control starts by the input end of material flow. It is designed to use less input of resource and energy to achieve the predestined goals of production and consumption, with particular attention to resource saving and pollution reduction at the outset of economic activities. In the process of production, without affecting product quality and safety, ecological design and advanced management methods are used to minimize the mass and energy in the production system of input materials and to reduce the emission of pollutants into the ecological system of nature. In the process of consumption, it is necessary to promote the ideas of saving and moderate consumption, encouraging a shift from excessive consumption to moderate consumption to green consumption and to advocate the purchase of endurable and recyclable articles rather than one-off articles for the purpose of garbage reduction.

2) Principle of Reuse

The principle of reuse requires that control takes place in all links of material flow process, emphasizing the repetitive use of products or the repetitive package of articles as much as possible within a life circle of material, with the objective of minimizing the use of resource and the emission of pollutants by extending the service life of products. In the process of production, standard sizes are used to make a design to make possible the technique of partially optimal substitution so as to avoid the scrapping of the whole product because of defective part. And it is important to use facilities and equipment of good production quality and high technique to extend the service life of fixed assets. In the process of consumption, it is required that people should repair the consumable products instead of frequent replacement, with the promotion of marketing of second-hand products. Repairable articles shall be returned to the market system for others’ use or donated unnecessary articles; or the repetitive use of packaging bags is encouraged to avoid the early retreat into garbage.

3) Principle of Recycling (Resource-Orientation)

The principle of recycling requires that control should be done at the input end of material flow, that is, resource-orientation enables wastes or rejected materials to become regenerative materials and to reproduce a primary or secondary product. On the one hand, there is a need to make comprehensive use of wastes produced within the production system to enable them to become the raw materials required by another production system at the maximum. On the other, old and disposable articles after consumption are treated for resource-orientation purpose and caused to become a kind of regenerative resource and form a regenerative product. Corresponding to the process of resource orientation, it is wise to encourage consumers and producers to purchase products finished by regenerative resources so as to enable the whole process of circular economy to have a good loop.

3R principles are not of equal importance in the circular economy, with their priority order of volume reduction, reuse and recycle (resource orientation). They have important points as follows: Firstly, it is important to reduce the emission volume of pollutants at the outset of economic activity. In other words, the emission of various wastes is avoided as much as possible in the phases of production, circulation and consumption. Secondly, rejected materials that can be used but not cut down as well as package materials or old goods that have been discarded by consumers should be recovered for reuse and returned to the process of circular economy. Finally, only those wastes of no use allows for the eventual no-harm disposal. For example, the *Law of Circular economy and Wastes Management* in Germany, effective in 1996, stipulates that the order of treatment of wastes is avoiding wastes, recycling use and ultimate disposal.

The priority order of 3R principles is an actual reflection of 3 phases of ideological advance regarding environment and development people went through in the second half of 20th century. Firstly, the idea of blind pursuit of economic growth at the expense of environmental destruction was rejected, moving from wastes emission to wastes purification (through end treatment); Next, wastes purification is shifted to wastes utilization (via reuse and recycle); Eventually, it is recognized that the reuse of wastes is still a complementary instrument, for the highest goal of the coordination between the environment and development is to realize a qualitative leap from the use of wastes to the reduction of wastes.

3. Roles of Circular Economy Development

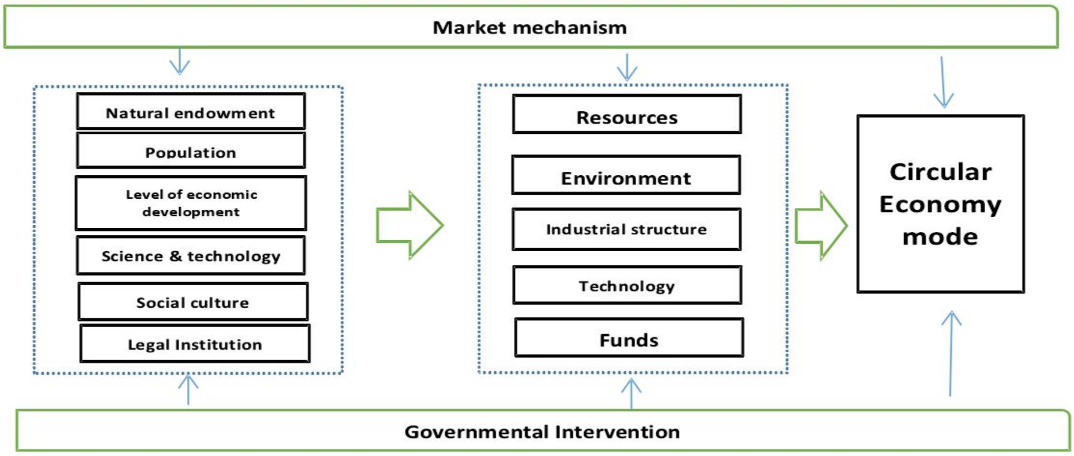
Firstly, circular economy development can fully improve the use efficiency of resource and energy as well as protect the ecological environment by minimizing the emission of wastes. Traditionally, industrial economy is an economy with single movement of material flow from resources to products to the emission of wastes and pollutants. In such an economy, people attempt to increasingly intensified effort to exploit and develop natural resources and energy, but in the course of production, processing and consumption, large amounts of pollutants and wastes are discharged into the environment. In a sense, it is a rather rough and one-off use of resources. Circular economy promotes an economic model built on the recycle use of materials, indicating that following such principles as volume reduction of resource input, extension of use life of products and services, and resource orientation of wastes, an economic activity is organized to constitute a recycling flow process from resources to products to regenerative resources and reproduction so that the overall economic system will basically have no or less wastes in the whole process of production and consumption to minimize the end treatment of wastes.

Secondly, circular economy development can realize the win-win of society, economy and environment. The resource use approach combining traditional linear economy with end treatment ignores the organic linkage and the coexistence relationship among industries within an economic structure; it also ignores development models such as transmission, transfer and recycle of mass, energy and information between socioeconomic system and natural ecological system, thus resulting in the scarcity and shortage of natural resources, with serious environmental pollution and big damage to economy and society, and human health as well. Circular economy takes the coordination of the relationship between human and nature as a guideline, that is, mocking the model and regular patter of operating natural ecological system and achieving the sustainable use of resources to enable social production to shift from the quantitative increase of materials to the qualitative increase. In the meanwhile, it also prolongs the production chain, promoting the development of environmental protection industry and other new industries, increasing employment opportunities and enhancing social development.

Thirdly, at different levels, circular economy development puts production and consumption into the framework of sustainable development whereas the development model of traditional industrial economy makes production and consumption separate, thus forming a vicious recycle of mass production, mass consumption and mass rejection. Presently, the practice of circular economy in advanced countries has established an organic linkage between production and consumption, the most important links, at the three levels as the following: first, clean production and recycling use of resource within an enterprise; second, ecological industry network among coexistent enterprises or industries, thirdly, the system of recovery and reuse of wastes in the regions and the whole society. Circular economy can integrate clean production, comprehensive resource use, ecological design and sustainable consumption into one, and can use the regular pattern of ecology to guide the economic activities of the human society, with the fundamental goal of protecting seriously scarce environmental resources and improving the allocation efficiency of environmental resources.

III. Analysis of Influencing Factors of Circular Economy Development

In additional to employing case study for analysis, scholars elaborate on the influencing factors of circular economy development from their respective perspectives. Ms Yu Lei (2009) classifies factors affecting the current promotion of circular economy development in China into five obstacles, namely, institutional obstacle, legal obstacle, ideological obstacle and social obstacle. Some scholars like Mr. Su (2013) comments on the process of PRC's circular economy from formulation of basic concepts to development and implementation, made comparisons of the current developments of circular economy of 4 pilot cities such as Beijing, Tianjin, Shanghai and Dalian and eventually summed up common restrictive factors: shortage of effective information platforms, shortage of standard evaluation system and shortage of strong public awareness. Since an enterprise is a practice unit of circular economy at the micro level, the implementation of circular economy with an enterprise determines to some extent the development level of circular economy in the industrial park, even in the region. Some scholars like Mr. Shi (2008) classifies factors affecting clean production into four types, namely, policy and market obstacle, financial and economic obstacle, technical and information obstacle, and managerial and organizational obstacle as well. Mr. Wu Baohua (2011) systemically sums up 3 types of factors affecting circular economy development such as direct factors, indirect factors and mechanical factors [4], covering various factors in the process of circular economy development (shown in Graph 1-1).



Graph 1-1: Various Factors of Circular Economy Development

1. Direct Factors

1) Resources. Theory and practice of circular economy are built on the human recognition of the scarcity of resource. Resource-related Factors such as storage capacity, availability, types and different combinations, dependency of industrial development, utilization means and use efficiency, directly affect the selection of circular economy model.
2) Environment. For human production and living activities, consideration must be given to the bearing capacity of the environment. Environmental pollution and excessive environmental pressure are common concerns for most of countries in the world at present. In China, types and extent of environmental issues vary from region to region, requiring that in selecting a model of circular economy, the development of circular economy be combined with environmental management based on the accurate understanding of environmental issues existing in different regions.
3) Industrial structure. Industrial structure and layout is one of the key factors vital to the success of circular economy development. While consideration is given to industrial structure and layout, only the integrated engagement of the sustainable supply of resources, ecological security of the environment and the green growth of economy can enable circular economy development to have a successfully reliable foundation. The industrial structure of a given region is the result of the interplay of natural endowment, economic development level and scientific and technological level of the region. The current status of the industrial structure constitutes a basis for the implementation of circular economy, affecting its promotion way. Therefore, the promotion of circular economy tends to be combined with the optimization of the industrial structure.
4) Technology. Circular economy is closely related to technology since its birth. Its central idea is “volume reduction, reuse and resource-orientation”, requiring that it can be achieved by corresponding technical instruments as a support. It is essential to rely on technical advance for the development of industries of resource recovery, regenerative resources and environment protection, the reshaping of traditional industries of big consumption and the realization of green ecological transformation of traditional industries. Technology is playing an increasingly important role in such aspects as improving resource utilization

efficiency, developing alternative resource and energy, decreasing the consumption of resources and energy, reducing the emission of pollutants and transforming wastes. While selecting modes of circular economy, consideration has to be given to technological level of the region and the cost and acquisition of technology required for the circular economy development.

5) Funds. High input is a basic characteristic and an important condition for circular economy development. The technology for circular economy is more complicated than that of the traditional technology, which tends to involve a number of disciplines and to have more stringent requirements for equipment and raw materials and more frequent technical renovations so that renovation and depreciation of corporate equipment can be speeded up. Therefore, the required fund amount for circular economy development is significantly higher than that of traditional industries. The innovation in the technology of circular economy requires large amounts of financial support, first turning academic outcomes into real productive force, in turn growing into one after one micro-systems of circular economy, and eventually forming more extensive intermediate and macro systems of circular economy. All in all, without great financial support, it is impossible to develop an effective circular economy.

2. Indirect Factors

1) Natural endowment. Natural endowment is a base on which all production and living activities of human being take place. It is not only fundamentally affecting all direct factors but also affecting other indirect factors. Different regions have varying natural endowments in terms of types and total volume, causing differences in resource and environment. Its effects over the economic development level also indirectly work on such factors as industrial structure and technological level. From the perspective of circular economy, natural endowment generally includes resources like minerals, land, water and climate, and so forth.
2) Population. To some degree, population is a variable of natural endowment. Per capita quantity of resources available can better explain the situation of resource and environment the human beings are confronted with than the total resource volume. China has a huge population that determines its common traits such as the shortage of resources and the pressure over the environment. In addition, population is also viewed as a kind of resource, that is, human resource. The theory of human capital and the theory of modern human resource development have revealed that human resource plays an enormous dynamic and contributive role in the aspects of economy and technological development.
3) Level of economic development. There is some interplay between the level of economic development of a given region and such factors as natural endowment, population and human resource, science & technology and social culture. What are more directly and more importantly affected by the local economic development level are resource demand, environmental pressure, industrial structure, technical level and capacity of fund supply within a given region.
4) Science & technology. The advance extent of science & technology tends to be relative to the level of economic development. As long as economic development can provide the support as needed, the higher the basic academic level and the stronger the academic force of a given region, the more powerful the capacity of technical innovation and extension of the region and the higher the probability of widespread technical application. Since its birth, circular economy has possessed

an obvious technical trait that its development is supported by immense technical innovation and diffusion.

5) Social culture. There is also interplay between social culture and other indirect factors. In the practice of circular economy, the understanding and recognition of circular economy constitutes a "soft" environment of circular economy development. Due to some concrete difference in social culture, different regions have varying understanding and recognition extent of the idea of circular economy. Such ideological and cognitive variations will not directly affect the selection of models of circular economy, but they will play a supportive or restrictive role in the development of circular economy.
6) Legal Institution. Without the security and promotion of legal institution, circular economy development will be made impossible. On the one hand, circular economy is a new thing that is not readily accepted owing to traditions and customs, but legal institution enjoys such characteristics as public selection, compulsion, authority and instant effects, thus allowing for the rapid promotion of circular economy. On the other hand, it calls for higher fund input, intelligence input and more self-restriction, thus increasing people's workload. Legal status of a particular region, in particular, the legislative perfection extent regarding circular economy will have an effect over the selection of models of circular economy and the selection of its promotion strategies.

3. Mechanism Factors.

1) Governmental Intervention. In the initial stage of circular economy, it is essential and extremely important for governments to play a promotional role, as evidenced by the creation of circular economy. Governmental role should use the effective play of markets as a prerequisite for fostering markets rather than replacing the markets, with an aim to provide public products and public services for the main body of market and to reduce their transitional costs. In practice, whether governmental agencies possess the corresponding awareness and capacity to carry out those obligations or duties and whether there are issues of "absence" or "displacement", will directly affect the speed and quality of regional circular economy development. In addition, it is only the government that plays a leading role in creating and updating an incentive and restrictive mechanism for circular economy.
2) Market mechanism. The theoretical prerequisite of circular economy is that natural resources are becoming a primary factor restricting the human development. It considers how to improve the resource use efficiency and the quality of economic development with a given resource storage capacity. Therefore, employing market mechanism to develop circular economy has higher efficiency and less management costs than using compulsory instruments, with particular focus on the important role of price leverage in the development of circular economy.

Chapter II Circular Economy Evaluation Indicators System and Methodology at Home and Abroad

I. Evaluation Indicators System & Methodology for American Circular Economy

1. Current Development Status of American Circular Economy

The development of circular economy is not only an important initiative for promoting economic advance in the USA, but also a part of daily life for the American general public. The USA is more a huge nation of resource consumption than a huge nation of production. In the past, it acquired resources from many other countries in a convenient and fast by buying low, so that it had a low rate of recovery and reuse of discarded articles. However, with the increasing destruction of resource environment and the constant enhancement of public awareness of environment protection, it is inevitable to alter the old idea of resource utilization and explore an approach to resource reuse based on the recovery and treatment of discarded articles. Circular economy instead of the traditional economy is an important shift to develop its economy by means of resource reuse. Over many years of exploration, the concept of circular economy has come to enter into the daily life of Americans.

The US government has attached great importance to its national circular economy development, constructing a model of circular economy development that is centered by governments, supported by enterprises and assured by citizens. It guides the participation of enterprises through the formulation of programs and plans, and sets about fostering the awareness of circular economy development of the citizens, thus promoting the rapid development of circular economy. Specifically, to promote the development of circular economy, the US government has adopted important steps as follows:

1) Formulating Plans and Legal Regulations Regarding Circular Economy

The USA has paid much attention to the formulation of development plans of circular economy development. The development plans set up explicit indicators to ensure the achievement of development objectives of circular economy. In the meanwhile, the counterpart laws and regulations of development planning have been refined. In the USA, all states enjoy their own laws and regulations, with some even developing their laws and regulations regarding the promotion of regeneration, recycle and reuse of resources according to their own realities.

2) Providing Powerful Technical Support

The USA has long encouraged all kinds of academic institutions to conduct researches on the recycle use of resources. On the one hand, the government provides research grants for the academic institution; on the other, advanced technologies are used to construct facilities for the recycle use of discarded articles or wastes. In addition, the US government has laid out various policies to encourage and support the research and development of recycle technology, including carrying out research and development as well as innovation activities for technologies of renewable energy sources and clean energy sources under the coordination and integrated planning of the government.

3) Urging Enterprises to Engage in Circular Economy Activities

The US government has formulated stringent legal regulations of environmental protection, explicitly stating the accountabilities of enterprises for wastes or rejected materials produced as well as the preferential policies with the above accountabilities in the process of treatment and production. Such practice has motivated the enterprises to actively participate in the activities of circular economy. Moreover, on the part of the enterprises themselves, resource-saving and promotion of renewable use of discarded materials not only build up a good corporate image as a responsible enterprise in the minds of the public, but also shape a good business brand for themselves with success brand effects.

4) Encouraging All Citizens to Involve in Circular Economy Activities

For the American general public, the awareness of their participation in the circular economy has been build up from many years of practice. On the one hand, the US government has launched education campaigns to gradually raise the people's awareness of resource-saving and environmental protection. For instance, November 15 is identified and observed annually as the Recycle Day in the USA. And some institutions like the National Renewable and Recycle Association annually provide awards to those agencies and individuals that reasonably carry out recycle use of resources; meanwhile they launch social campaigns to encourage more agencies and individuals to engage in the circular economy. On the other hand, the US government has used "second-hand" business transaction to conduct circular economy activities. For example, eBy is an American website that deals with selling old articles at auction, a big feature of the development of circular economy in the USA. It is a website through which the public can freely trade some second-hand articles, realizing the second-time distribution of resources [5].

2. Composition of Evaluation Indicators System of American Circular Economy

In June, 1992, the Environment and Development Conference held by the United Nations in Rio De Janeiro, Brazil called on all international institutions and NGOs to establish and apply an indicators system of sustainable development. From then on, there has been a succession of relevant indicators systems associated with the environment and sustainable development, to name a few, the indicators system of Motivation –Status – Response developed by the UNCSD, the framework of indicators system of sustainable development issued by the UNSTAT, a set of highly consolidated indicators system of sustainable development proposed in the *Report of Human Development* jointly prepared by the SCOPE and the UNEP.

In the late 1980s, Mr. H.T.Odum, a well-known American ecologist, developed an indicators system named "Emergy Theory". In the 1990s, Austria, Germany, Japan, the Holland and the USA jointly developed an accounting system of material flow. In 1997, the USA World Resources Institute (WRI) took the lead in publishing the collaborative results of those countries in the report of *National Weight*. The report developed such concepts as direct materials input, domestic process output, which are used for showing one nation's number of indicators system of material flow. In 1997, American ecologist Brown M.T. and Italian ecologist Ulgiati S developed the first ESI (Energy Sustainability Indicators). With the development of environment protection movement and the popularity of the idea of sustainable development, some economists and statisticians attempt to include an environmental element – Green GDP in the accounting system of national economy to develop a new accounting system of national economy. As an adjustment to the GDP indicators system, it is a GDP after the environment cost for one economic activity is deducted.

The term "ecological efficiency" is derived from ecology. It refers to the efficiency of energy use of all living beings that need nutrition in the process of energy flow with the ecological system, expressed in the specific value among different points on the line of energy flow [6]. Since the 1990s, the concept of ecological efficiency has been introduced the field of sustainable development. In 1990, Mr. Schahegger and Sturm developed the first measurement indicator system of environmental performance – ecological efficiency, which is in line with the guideline and purpose of circular economy of using less resource to create more value [7].

Table 2-1 Indicators System of Ecological Efficiency

Category	Indicators
Input	Resource and energy consumed by enterprise production or economy bodies as well as environmental overload arising from the consumption
Output	Value of products and services provided by corporate production or economy bodies

3. Evaluation Methods of American Circular Economy

Emergy analysis method is a method commonly used in systemic ecology, using energy as a measurement unit. Overall, it is a discussion on the energy flow between the human society and the natural environment. Using solar energy as a basic unit, emergy includes quantity (energy) and quality (obtained from energy conversion rate). It uses emergy indicators to determine the relationship between natural resources and human activities. In accordance with the principle of energy conservation, when natural resource is used and converted into other form of energy, the energy before the conversion is equal to that after the conversion. The emergy analysis method is employed to evaluate the development of circular economy, the resource as the input end and the product and the waste as the output end can be turned into equivalent units of energy, thus judging the energy use efficiency and energy recycle efficiency of the whole system of circular economy.

Material flow method is defined as a way of analyzing the status of material flow in an economic activity and measuring efficiency, resource and environmental pressure by establishing a corresponding indicators system in the economic activity. Based on the input and output of material, it uses quantitative analysis to establish an account of material input and output so as to evaluate circular economy and better manage it based on material flow.

Life cycle analysis method is an objective process of evaluating the environmental bearing capacity caused by products, production process and activities. It is recognized and quantified by the utilization of energy and materials and the emission of environmental wastes arising from it so that the effects of the utilization over the environment are measured in order to seek an approach for improvement. The evaluation method uses the input and output of materials and energy in the process of creating a product to work out the input volume of resource and energy of the product as well as the kinds and quantities of environmental released materials and types and degrees of related environmental effects, thus altering raw materials and energy composition, improving production process and bettering the management methods of rejected materials and so forth for better environmental and social benefits. The economic system of circular economy is required to reduce the pollutant output flow while decreasing the resource input flow. As a result, the method makes an analysis of materials consumption and pollutants emission in the whole process of circulation of resource and energy, thus obtaining the information on the material flow and environmental impacts in the overall process and system to make an evaluation on the ecological and economic benefits of the whole system.

4. Experiences Obtained and Lessons Learnt

Circular economy has become one of important instruments of the American economic development. The experiences accumulated and lesions learnt in the development of circular economy of the United States can be taken as a useful reference for the PRC. Firstly, the governmental authorities must play a leading role in the national development of circular economy by formulating special laws and regulation of circular economy and *Development Program of Circular economy* to promote the development of national circular economy. Secondly, the active participation of all walks of life is an important assurance for the successful development of circular economy, thus it is essential to entice enterprises, nonprofit institutions and individuals to actively involve themselves in the development of circular economy; Thirdly, all kinds of media shall be employed to launch campaigns to spread the information on circular economy and to promote all citizens' involvement in the development of circular economy, all of which constitute an important basis for the sustainable development of circular economy.

II. Evaluation Indicators System & Methodology of German Circular economy

1. Present Development Status of German Circular Economy

In the late 1980s, the circular economy in Germany gradually developed and flourished. Rigorous Germans promoted the development of the German circular economy through the establishment of a support mechanism of the system. In particular, they created a perfect and featured system of wastes management. Germany is one of the earliest countries that made legislations concerning circular economy. Germany developed and promulgated its *Law of Wastes Treatment* as early as 1972, its new Law of Wastes Management in 1986, and its *Material Loop Recycle and Wastes Management* in 1994 which made the first reference to the term "circular economy". On such basis, Germany laid out the *Law of Circular economy and Wastes Management* in 1996, which has created and established such principles as the Minimum of Wastes, the Trouble-maker and the Cooperation of Citizens, indicating an enterprise's accountability in the development of circular economy and advocating that all enterprises take the idea of circular economy as an integral part of their respective self-development.

The high development of the German recycle development is mainly attributed to coming to grips with the key issues of their own country's development of circular economy as well as the support mechanism associated with them. Germany has carried out major practices in the development of circular economy as follow:

1) Developing the Laws and Regulations regarding Circular Economy Development

To promote the development of circular economy, Germany has laid out a succession of laws and regulations associated with it, with particular preference to the management of wastes or rejected materials. The *Law of Circular economy and Wastes Management* promulgated and implemented by the German Government in 1996 is symbolic of its mature legal system regarding the support of circular economy development. It explicitly states adopting the measure of volume reduction to lessen the production amount of wastes as well as the primary responsibilities and obligations of wastes producers, owners and wastes disposers, with particular emphasis on and stipulation of the government's exemplary role. Within the framework of the *Law of Circular economy and Wastes Management*, based on the realities of different sectors, the German Government has formulated and promoted the laws and regulations concerning circular economy development in the sectors, such as *Stipulations on Cash Pledge for Beverage Packaging*, *Regulations for the Treatment of Old Discarded Automobiles* and *Treatment Methods for Rejected Wooden Materials*. They make specific stipulation as to the treatment of old discarded articles, thus enabling the support mechanism of circular economy development to be increasingly perfect and noticeably effective.

2) Setting up Garbage Reuse Service Companies

Unlike the common governmental guidance in other countries, Germany has also set up a range of NGOs, that is, companies that can provide garbage reuse services. The companies provide not only garbage recovery and reuse services for the enterprises lacking techniques of garbage treatment, but also technical consultations for those enterprises that have already establish their system of garbage recovery and reuse, thus highlighting the role of garbage reuse service companies. On one hand, it supplements the inadequacy of the government's failure to engage in all enterprises in the development of circular economy. On the other hand, it also fulfills the need of enterprises with the intent to construct system of free garbage treatment.

3) Establishing a Supervision Mechanism for Circular Economy Development

As a significant feedback mechanism in the economic development, supervision mechanism plays an important role in the development of circular economy. Germany has established a range of specialized institutions that exclusively supervise wastes recovery of enterprises and execute regulations regarding circular economy development, meanwhile, it requires that producers provide proof to supervisory institutions that they are capable of recovering old discarded products before they can engage in the activities of production and marketing, and that garbage kinds, scales and treatment measures with respect to production of enterprises also need to be reported to the institutions prior to the event. For those dangerous and harmful production enterprises with an annual wastes emission of more than 2000 tons, it is also necessary to submit their proposals of wastes treatment [5].

2. Composition of Evaluation Indicators System of German Circular Economy

In the early 1990s, the German Wuppertal Institute developed a system of Material Flow Accounts, MFA [8]. Over the past few years, various kinds of MFA have made much headway in their improvement and standardization. As known to us all, the EU has established a set of comprehensive national accounting criteria of material flow. In 2001, based on the preparation of MFA, the EUROSTAR worked out a set of indicators system that describes material flow, which can be used for representing material input, consumption, output and foreign trade balance within the whole socioeconomic context of a given country or region and developed the *Guideline for Economical Material Flow Accounting and Derivations*. The guideline has provided a general framework for the EU countries preparing the material flow accounting and consolidated balance within the whole socioeconomic context.

Table 2-2 German Indicators System of Material Flow

Category	Indicators
Input	Direct Material Input（DMI）
	Total Material Input（TMI）
	Total Material Requirement（TMR）
Consumption	Domestic Material Consumption（DMC）
	Total Material Consumption（TMC）
	Physical Trade Balance（PTB）
Output	Domestic Process Output（DPO）
	Total Domestic Output（TDO）
	Domestic Material Output（DMO）
	Total Material Output（TMO）

1) Input Indicators

Direct material input (DMI) is used to measure the director material input in an economic activity. That is, it refers to all materials of economic value that are mined

in the natural environment and used in the activities of production and consumption. Its formula goes like this: DMI = the raw material of domestic mining + imported materials.
Total material input (TMI) includes the direct material input as well as the materials that are mined in the natural environment but not used for production and consumption in the economic activity. Its formula is: TMI = DMI + domestic recessive material input.

Total Material Requirement (TMR) refers to TMI plus the recessive material accompanied by the corresponding imported material in the imported country, indicating the overall material foundation supporting the whole society. Its formula is: TMR = TMI+ the recessive material accompanied by the corresponding imported material in the imported country.

2) Consumption Indicators

Domestic Material Consumption (DMC) measures the total material volume directly used in the economic activities of the whole society, with its formula of DMC = DMI – Exported material.

Total Material Consumption (TMC) is used to measure the total volume of material directly used in the production and consumption of the whole society, including the recessive material accompanied by the corresponding imported material, with its formula of TMC = TMR – (Exported material + the recessive material accompanied by the corresponding imported material.
Physical Trade Balance (PTB) is a measurement of surplus or deficit of the physical trade balance. Its formula goes like this: PTB = the imported material + exported material.

3) Output Indicators

Domestic Process Output refers to the domestic material input that enters into the boundary of an economic activity of social production and consumption, a considerable part of material becomes the increased stock still left with the boundary of social economic activity, including newly constructed buildings and goods for capital construction, increased material in the commodity inventories, newly purchased institutional equipment and communication facilities, and endurable consumer goods such as electrical appliances and furniture as well. Other goods are discharged within the boundary of economic activity into the natural environment in the chain of activities such as transport, processing, manufacturing, use and production and consumption to be eventually treated, the total material volume of the goods is called DPO. It includes wastes or rejected materials discharged into the atmosphere, industrial and urban solid materials, wastes that enter into water bodies, and wastes that flow into the environment by spraying and scattering.

Total Domestic Output is the total of wastes that enter into the environment through the DPO and recessive mining output, an indicator for the total volume of environmental wastes caused by the economic activity.

Direct Material Output is the sum of DPO and the exported volume, an indicator showing all the total volume of materials re-discharged into the domestic environment after leaving the social and economic activities.

Total Material Output is the total volume of materials re-discharged into the domestic environment as a result of the social and economic activities, that is, it is the total of TDO plus the exported materials.

3. Evaluation Methodology of German Circular Economy

Material flow analysis is an analysis of material flow in an economic activity. It is built on the quantitative analysis of material input and output by establishing an account of material input and output for the optimal management based on the material flow. It is used to measure the material input and output as well as the material use efficiency associated with a socioeconomic activity. It falls into the category of the application of mass amount evaluation method in the quantitative assessment methodology of ecological economy system. It is known that circular economy puts emphasis on the reduction of resource consumption, the effective use of resource and the reduction of pollutants emission at the outset. Material flow analysis is an important technical support of circular economy, thus the evaluation method of indicators system based on the analysis of material flow is an important method for evaluating the development of circular economy. In terms of circular economy, the material flow analysis can describe in a quantitative way the relationships of the consumption of natural resources and the human economic activities, the production of wastes and the human economic activities, and the reuse of wastes and the renewable use of resource as well.

Evaluation method of comprehensive index is an evaluation method of comprehensive indicators system by which typical property parameters of an evaluation object are extracted to identify indicators of evaluation according to its characteristics and evaluation purpose and requirements and then the advantages and disadvantages are weighed down based on the evaluations standards. It makes a comprehensive assessment adopting the weight arithmetic average formula in accordance with the fundamental principle of index analysis. It is achieved by using the average value of each indicator as the criteria of evaluation to turn the indicators of different dimensions into comparable statistical indexes, thus enabling them to be comparable. The evaluation procedure goes as follows: first determining the weight of an evaluation object, then calculating the comprehensive average indicators of each subsystem and at last obtaining the comprehensive average indexes.

4. Experiences Obtained and Lessons Learnt

1) Making Special Legislations in a Targeted Manner

It can be seen from the overview of the development of circular economy in Germany that its legislations is highly targeted. In responsive to the priority of material recovery and reuse, Germany has promulgated a succession of special laws and regulations regarding packaging, discarded automobiles, electronic equipment, building garbage and domestic living garbage. The systematical establishment of the special laws and regulations has enabled Germany to occupy a globally leading position in the treatment of wastes or rejected materials. Based on the realities of the circular economy development in the PRC, in addition to the fundamental laws, it is important to make targeted and prioritized special legislations and intensify the implementation efforts of circular economy laws and regulations by means of point-to-area, thus creating a good condition for the promotion of its overall development.

2) Encouraging NGO Intervention

The mode of DSD for collect and treating wastes package is a typical mode established in the practice of circular economy in Germany. The Chinese government can replicate the DSD mode of German by encouraging the involvement of NGOs in the sectors of wastes package recovery and use in order to realize the reuse of resource. NGO intervention will offer more choices for enterprises to develop the circular economy, while helping the enterprises to establish systems of recovery and use and resource-orientation.

3) Setting up Corresponding Supervisory Institutions

The establishment of supervisory agencies for circular economy in Germany has made possible the initiatives of circular economy in the aspects of production and marketing of enterprises. In the implementation of circular economy in the PRC, in additional to oriental guidance, more importantly, the government offered enterprises some supervisions and professional guidance at the initial stage of development, thus promoting the circular economy to the standardization and normalization as soon as possible. In the formative period of circular economy development, enterprises generally do not automatically carry out the practice of circular economy out of costs production, thus it is necessary for the supervisory agencies to give introduction and guidance. The performance of the enterprises engaging in the practice of circular economy requires the review and appraisal of the supervision agencies, thus enabling the establishment of supervision structure regarding circular economy to become essential. The supervision institutions, by means of evaluation and feedback, offer orientation and assistance for the enterprises in carrying out the practice of circular economy and in recommending improvement measures, ultimately ensuring the sound implementation of circular economy of the nation.

III. Evaluation Indicators System & Methodology of Japanese Circular Economy

1. Current Development Status of Japanese Circular Economy

Since World War II, the rapid growth of Japanese economy has enabled Japan, a nation with small land area and resource-deficiency, to experience the greater resource and environmental pressure. With the shift of domestic wastes from the industrial pollution-free treatment to the control of living pollutants, the Japanese Government has laid out a succession of strategies and programs from time to time, with its strategic intents being constantly realized in the planned implementation process. Through many years of efforts, Japan has become one of the nations with mature circular economy development, particularly, in the construction of legal system of circular economy, with its experiences and lessons frequently borrowed by other countries.

Japan has established a recycle-based society, which is manifested in three important aspects as follows: environmental industrialization (developing "venous" industries), industrial environment (developing environmental-friendly arterial industries), "venous" and "arterial" combination or connection to material flow balance. As early as 2000, the Japanese Government issued the *Fundamental Laws for Formation and Promotion of A Recycle-based Society in Japan,* which upholds the construction of a recycle-based sustainable development society as the overall development goal of the Japanese economic society. Presently, Japan has established an improved system of laws and regulations regarding circular economy, thus ensuring the development of circular economy in Japan.

1) Legally Ensuring the Establishment of A system of Circular Economy

In terms of system of laws and regulations, Japan has established a rather complete system of laws and regulations regarding circular economy, mainly at the following 3 levels: the fundamental laws based on the *Fundamental Laws for Formation and Promotion of A Recycle-based Society in Japan*, the comprehensive laws based on the *law of Wastes Treatment* and the *Law on the Promotion of Effective Resource Use*, the special laws based on the *Law on the Renewable Use of Electrical Appliances*, the *Law on the Renewable Use of Automobiles*, the *Law on the Renewable Use of Building Materials*, the *Law on the Renewable Use of Packaging Containers*, the *Law on the Renewable Use of Food* and the *Law of Green Purchase*. It is noted that the *Fundamental Laws for Formation and Promotion of A Recycle-based Society in Japan* is mainly based on the industrial economic chain of "producer – consumer – disintegrator", requiring that Japan ultimately form a circular economy network of mutual benefit and coexistence, thus achieving a loop recycle of material energy flow.

2) Promoting the building of a Recycle-based Society Helped by Economic Policies

For the promotion of the development of a recycle-based society, Japan has implemented a succession of economic policies, of which the most important one that runs through the establishment of a recycle-based society in the whole Japan is the system of compensation allowance for ecological parks. The main contents of the system are as follows: The Ministry of Environment finances the construction of soft facilities; the Ministry of Economy, Trade and Industry provides hard facilities; local governments construct infrastructures; and projects that involve other departments or agencies are sponsored by the responsible agencies. In the execution of 6 special laws, Japan has developed a detailed economic system according to the characteristics of each special law, thus ensuring that discarded home electrical appliances, automobiles packaging materials and building structures can be better recovered and reused[5].

2. Composition of Evaluation Indicators System of Japanese Circular Economy

In the promotion of circular economy development, Japan has been at the globally leading level. Based on the establishment of a legal system of circular economy, it has explicitly formulated a program of promoting a recycle-based society and developed detailed development objectives adopting the analysis of material flow. Through the analysis method of material flow, Japan made an analysis of national macro material flow during the period from 1982 to 2000 in Japan, basically perfecting indicators of circular economy. At the outset, Japan developed 6 recycle economic indicators in the aspects such as resource input, production, consumption and final wastes disposal, including:

Table 2-3 Japanese Indicators System of Material Flow

Types	Indicators
Recycle Use of Materials	Total Material Input
	Total Material Input
Input and Output	Resource Recycling Rate of Wastes
	Recycle Use Rate of Wastes
Production and Consumption	Resource Use Efficiency
	Resource Use Time

2 indicators such as direct material input and direct material output are used to measure the reduction of mining output of natural resources and the decrease in environmental overload; while 2 indicators such as resource recycling rate of wastes and recycle use rate of wastes are used to measure recycle use rate of wastes in terms of input and output. And resource use efficiency and resource use time are used to indicate the extent of "effective use" of resource in all aspects of production and consumption.

Through many years of researches on MFA methods and circular economy, Japan has finally identified 3 of the above-mentioned indicators as the core indicators of circular economy. They include: (a) resource production rate, a ratio of national GDP of the year and direct material input, as revised by combining direct material input indicator with economic indicators; (b) recycle use rate of wastes, including recycle and reuse of wastes after consumption as well as recycle use of wastes produced one production after production; (c) ultimate disposal volume of wastes, as Japan has reduced the scope of direct material output to, including the volume of materials discharged into the natural environment through the final disposal of industrial and urban garbage. Other indicators including resource recycling use of wastes are set up as internal targets of each product by each agency. Indicators such as resource use efficiency and resource use life deserve information collocation and research.

3. Evaluation Methods of Japanese Circular Economy

Analysis method of material flow is a method of the systematical analysis of material flow and storage regarding economic system within a given scope of time and space, involving the source, path and convergence of material flow. In accordance of the law of mass conversation, the result of material flow analysis has been the realization of ultimate material balance in the process of input, storage and output. It is a noticeable characteristic of material flow analysis, providing a methodological instrument of policy support for resources, wastes and environmental management. In the early 1990s, Austria, Japan and Germany first used the analysis method of material flow to conduct an analysis of the flow status of natural resources and materials of their respective national economic system, thus revealing a prelude of the widespread application worldwide of the analysis method of material flow of economic system [9].

Cost-effective method, based on the principle of rational distribution of resource, is used to examine the cost and effectiveness of items from the national overall perspective, and taking shadow price as the primary train of thought and employing the impact method as a supplementary and using such economic parameters as shadow price of goods, shadow salary and social discount rate, to analyze and calculate the net contributions of relevant items to national economy and evaluate their economic rationality. The cost-effective analysis is a process in which a contrast is made of the costs of constructional investments required by project construction and implementation and the benefits produced arising from them in order to analyze the feasibility of the project, taking the improvement of socioeconomic efficiency as the criterion. Shadow price, also referred to as the price of efficiency, is essentially a content of internal value of economic resource, a price ensuring the optimal use of resource and a core instrument of cost-effective analysis. Through the value assessment of ecological environmental impacts, it includes one’s environmental concern in the feasibility study of the project, thus serving as a bridge established between the benefit analysis of circular economy and the environmental impact assessment of development projects.

4. Experiences Obtained and Lessons Learnt

There are many similarities in the environmental issues encountered between the period of rapid economic growth in China and that in Japan. For urban domestic garbage, China has a hazard-free treatment of only 6 percent at present, with more than 300 cities surrounded by living garbage. The historical process of environmental management in Japan, in particular, the practice of its establishment a recycle-based economic society, has provided an important reference for China in exploring a practice mode of circular economy with Chinese characteristics. Firstly, the formulation of relevant laws and regulations is a fundamental prerequisite of circular economy development and the perfection of legal systems can promote the participation of enterprises and the general public in circular economy development. Secondly, mechanism construction should be synchronized with social construction, for refined operational mechanism and reliable system construction constitute an assurance for developing a society based on circular economy.

IV. Evaluation Indicators System and Methodology of Chinese Circular Economy

1. Present Development Status of Chinese Circular Economy

Since the concept of circular economy was introduced in the late 1990s, it has aroused the attentions of the academic world and the decision-making management in the field of theoretical research and practices. Since 2002, the research literature concerning circular economy has mushroomed, with a rapid spurt. In 2005, the State Council of China issued a document entitled the *Opinions on the Acceleration of Circular* *economy Development*, establishing the guidelines, fundamental principles and strategic goals for the domestic circular economy development. Later on, the acceleration of circular economy development has already become an important strategic initiative for the adequate implementation and realization of the concept of scientific development, the overall construction of a "Xiaokang" society and the achievement of sustainable development. Over years of exploration, the research concerning circular economy in China has developed from the stage of spreading of idea and interpretation of concept to the stage of construction of theoretical system, with important outcomes in many ways. In 2013, the State Council issued an official document named the *Strategies and Near-term Action Plan regarding Circular economy Development*. It is the first important document of the national strategies and special program regarding circular economy development in China which has proposed a number of innovative points in terms of train of thought, contents, system and mechanism in response to priorities, difficulties and hot issues of circular economy development.

Since 1999, based on the research and absorption of internal experiences and practices of circular economy development, the State Environment Protection Administration (SEPA) has made many attempts in the theoretical exploration and practice of circular economy at the levels of enterprises, regions and the society, by setting about tackling the issues of industrial pollution and urban pollution and through multiple modes such as the promotion of clean production, the creation of ecological industrial parks and the building of a society of circular economy. In 2003, the SEPA made further steps to introduce the idea of ecological industry to all kinds of economic development zones and high-tech zones with complete industrial types and strong economic integration and to carry out the extensive work of constructing ecological industrial parks, thus enabling the construction to enter into a new stage.

In recent years, China has gradually carried out explorations and practices of circular economy at the three levels, with remarkable effects as follows:

Clean production is actively promoted at the level of small recycle. China is one of the internationally accepted developing nations with best clean production. In 2002, the PRC promulgated the *Law of the Promotion of Clean Production*. Up to now, it has carried out clean production audits in the enterprises of over 20 sectors in more than 20 provinces (regions or municipalities), built 20 industrial or local clean production centers and conducted various types of training courses on clean production with an attendance record of over 10000 person/times. There are more than 5000 enterprises that have gone through the environment management system certification of ISO14000, with hundreds of products obtaining environment labeling.

At the level of intermediate recycle, according to the idea of circular economy, ecological industrial parks are built, consisting of coexistent enterprise groups. It is important to establish the ecological industrial parks in the areas or development zones of relatively concentrated enterprises. Following the law of ecology, they are organized to engage in the production by turning the wastes from the upstream enterprises into the raw materials of the downstream enterprises so as to minimize pollutants emission and strive for "Zero Emission". Specifically, they include the Guigang National Ecological Industrial Park, the Nanhai National Ecological Industrial Park, the Quzhou Shengjia Ecological Industrial Park, the Ecological

Industrial Park of Tianjin Economic and Technological Development Zone and the Yantai Development Zone Ecological Industrial Park, and so forth.

When it comes to the pilot work of circular economy at the province and municipal levels, such provinces and municipalities as Liaoning, Guiyang and Qinghai have begun to explore modes of circular economy development at the regional level. Liaoning Province has fully emerged the idea of circular economy into the industrial restructuring of old industrial bases. And through formulating and implementing the systems of legal and economic measures regarding circular economy, it has attempted construct a batch of recycle-oriented enterprises, ecological industrial parks, recycle-oriented cities as well as a system of urban renewable resource recovery and regenerative industries, so that they can take full advantage of local resources and technologies, optimize industrial structure and layout, push regional economy development, create more employment opportunities, thus promoting the overall synergic economic, social and environmental development. Guiyang Municipality has promulgated the first document of legal regulations on circular economy, thus providing a legal assurance for the promotion of circular economy construction. In line with the goal of constructing national circular economy development pilot zones and insisting on the development of circular economy as the major attack orientation of transformation development modes, Qinghai Province takes advantage of resources such as salt lakes, petrol and gas, coal and nonferrous metal to initially construct an industrial framework and to constantly extend industrial chains, thus its industrial parks have played a noticeably demonstrative and driving role, its infrastructure has been gradually updated, and its scientific and technological support has been remarkably strengthened. In the development of local economy, Guangdong Province, Zhejiang Province and Shanghai Municipality have begun paying much attention to such issues as energy consumption, social equitability and human development in the economic development. During the period of the Twelfth Five-Year Plan, China implemented 10 key projects of circular economy, created 100 demonstration cities of circular economy, fostered 1000 demonstration enterprises of circular economy, thus promoting the establishment of a big scale circular economy.

In addition, the Province of Guangdong has prepared a Program of Environmental Protection of the Pearl River Delta Zone which develops the guideline of “People First with Environment Priority” and identifies the “three strategic lines”, that is, the blue line of optimizing the socioeconomic layout, the green line of developing circular economy and the red line of controlling environmental pollution. The Province of Zhejiang has also proposed the construction of an ecological economy system with the core of circular economy. Shanghai is the first city to have launched the research on circular economy development strategies. It has already included relevant concepts and ideas of circular economy in the *China 20th-Century Agenda-Shanghai Action Plan*, which develops the development strategies and implementation Plan of Circular economy of Shanghai Municipality and proposes the concept of constructing an international circular economy metropolis. In the meanwhile, the provinces such as Jiangsu, Shandong, Heilongjiang and Gansu are also actively promoting the development of circular economy. In a sense, circular economy has been gradually extended from industry and environment protection to all aspects of the economic society.

2. Composition of Evaluation Indicators System of Chinese Circular Economy

1) Research on the Evaluation Indicators System at the Social Level

The evaluation indicators system at the social level is a basis and criterion for the comprehensive evaluation and research of the situation of synergic development of regional social, economic and ecological environmental systems, and an orderly assembly of indicators of different properties adequately reflecting the social, economic and ecological environmental systems that is organized according to the principles of subordinate and hierarchical relations. Ms. Zhou Guomei from the Policy Research Center of the SEPA and Mr. Liu Bing from the Tsinghua University conducted researches on the national experiences and methods regarding material flow analysis and material flow management by analyzing the close relationship between material flow analysis and management as well as circular economy in the two aspects of total volume and intensity of material use, and developed an evaluation indicators system [10].

The research on the evaluation indicators system of circular economy has also drawn the high attention of the state. Mr. Duan Ning, vice president of the China Academy of Sciences, is charge of the national science & technology strategic program of "Research on Ecological Industrial Technology of Circular Economy Theory under the direct care of Mr. Xie Zhenhua, general director of the SEPA. Subject 3 under the program serves as a guideline of indicators and plans regarding circular economy and ecological industry.

The Environment and Resources Committee of the National Congress, in collaboration with the Outstanding Committee of the Shanghai Congress, have organized experts and scholars from relevant departments and agencies to set up a research project team of theories and methods of China circular economy. The team led by Mr. Fen Zhijun made a tentative exploration of evaluation indicators system of circular economy by separating circular economy into 3 subsystems of economic, social and ecologically environmental recycles for evaluation [11].

Ms. Niu Guiming (2005) from the Tianjin Academy of Social Sciences conducted research on the establishment of evaluation system of circular economy in accordance with implications and objectives of circular economy and in line with its establishment principle. Based on the current statistical indicators system of national economy, the research added indicators reflecting material input, emission, use efficiency and recycle use in a socioeconomic activity [12].

In 2007, the National Development and Reform Commission, the SEPA and the National Statistics Bureau jointly prepared and issued a document entitled the *Evaluation Indicators System of Circular economy*, which stipulates 22 evaluation indicators of circular economy at the macro level in the four aspects such as resource output, resource consumption, integrated resource utilization and wastes emission. The indicator of resource output mainly refers to the National GDP arising from one-time consumption of resource. The higher the indicator is, the better the use efficiency of natural resources is. The indicator of resource consumption mainly describes the resource consumed by per unit of product or per unit of GDP, reflecting resource saving and consumption decrease, the promotion of "volume reduction" and the decrease in resource consumption at the outset. The indicator of integrated use of resource shows the resource recycling extent of such wastes as industrial solid waste, industrial water waste and urban living garbage and the recovery and use of five types of discarded articles, embodying the requirements for the transformation of wastes into resource, the saving and use of resource and the recycle use of resource, that is, the effects of “resource recycling”. The indicator of wastes emission is mainly used to describe the ultimate emission of industrial solid waste, industrial waste water, sulfur dioxide and COD, which reflects the results obtained from the reduction of resource consumption and wastes occurrence, the decrease of ultimate emission of wastes and the lessening of environmental pollution through volume reduction, reuse and resource recycle.

Table 2-4 Evaluation Indicators System of Circular economy at the Macro Level

Types	Indicators (rates)	Types	Indicators
Resource Output	Output of primary mineral resources	Resource consumption	Consumption of GDP per unit
	Output of energy resource		Consumption of industrial value-added per unit
Integrated Resource Use	Integrated use of industrial solid wastes		Integrated energy consumption of primary products per unit in priority sectors
	Repetitive use of industrial water		Water requirement of GDP per unit
	Renewable Use of urban sewage		Water requirement of industrial value-added per unit
	Hazard-free treatment of urban living garbage		Water Consumption of product per unit in priority sectors
	Recovery and use of rejected iron and steel		Effective use coefficient of agricultural irrigation water.
	Recovery and use of rejected nonferrous metals		Disposal amount of industrial solid wastes
	Recovery and use of waste paper		Emission of industrial waste water
	Recovery and use of waste plastic		Emission of sulfur dioxide
	Recovery and use of waste rubber		COD emission

2) Research on the Evaluation Indicators System at the Park Level

Ecological industrial park is an important form of circular economy. In 1999, China created the first national ecological industrial park that has achieved the adequate sharing of resource and the transformation of negative pollution impacts into positive resource benefits in all aspects of industries. At present, the research on the ecological industrial park focuses more on the ideas /trains of thought and ecological planning of industrial park construction, with less focus on the research on evaluation indicators system of ecological industrial parks.

Mr. Yuan Tonglian (2003) from the National Center of Clean Production conducts research on evaluation indicators system of ecological industrial parks and proposes a framework of the system of evaluation indicators, including economic indicators, ecological environmental indicators, ecological network indicators and management indicators. The economic indicators consist of indicators that reflect the current level of economic development and the potential of economic development. The ecological environmental indicator includes such aspects as environmental protection, ecological construction and ecological environmental improvement. The ecological network indicator is a characteristic indicator of industrial ecological parks that shows the effects of material integration, energy integration, water resource integration, information sharing and infrastructure sharing. The management indicator covers policy related legal codes and systems, management and awareness [13]. In 2007, the National Development and Reform Commission, the SEPA and the National Statistics Bureau jointly prepared and issued a document entitled the *Evaluation Indicators System of Recycle*, which stipulates 14 evaluation indicators of circular economy at the industrial park level in the four aspects such as resource output, resource consumption, integrated resource utilization and wastes emission. The indicator of resource output rate includes such rates as output of primary mineral resources, energy output, land output and water resource output. The indicator of resource consumption consists of energy consumption of GDP per unit, water requirement of GDP per unit, energy consumption of priority product per unit and water consumption of priority product per unit. The indicator of integrated resource use includes integrated use rate of industrial solid wastes and repetitive use rate of industrial water. The indicator of wastes emission covers disposal amount of industrial solid wastes, emission amount of industrial waste water, emission amount of sulfur dioxide and emission amount of COD. Such evaluation indicators are mainly used for quantitative evaluation and description of the development of circular economy, thus providing guidance for the circular economy development in the ecological industrial parks.

3) Research on the Evaluation Indicators System at the enterprise Level

There has been less research literature on the evaluation indicators system at the enterprise level. Mr. Li Jian (2004) from the Economics College of Nankai University examins the structure of evaluation indicators system of circular economy with respect to enterprise performance and evaluation methods as well. He held that in evaluating the enterprise performance, comprehensive consideration should be given to the effects over the enterprises from such aspects as business effect, green effect, energy property, production process property, market and consumption property, environmental effect and development potential and he sets up corresponding indicators for each aspect, thus establishing an evaluation system with many targets [14]. Mr. Chen Yong (2009) contends that iron and steel sector is a pilot sector of circular economy development in China, so the research on the evaluation indicators system of circular economy of iron and steel enterprises is not only a realistic requirement for guiding the enterprises in the better development of circular economy, but also an objective need for speeding up the national circular economy in the PRC. To this end, he made references to the indicators systems from the *Study on the Evaluation Indicators System of Circular economy regarding Mineral Resources* issued by the Ministry of National Land and Resources and the *Evaluation System of Clean Production in Iron and Steel Sector (Trial)* issued by the National Development and Reform Commission and constructed an evaluation indicators system for the development level of circular economy for iron and steel enterprises using the Panzhihua Steel Plan as the setting [15]. Mr. Liu Chuangen (2009) argues that circular economy development is an inevitable choice of the construction of harmonious mining areas and the realization of the sustainable development, and he established an integrated evaluation indicators system of circular economy for coal enterprises using Xishan Company, Ltd as the setting [16].

3. Evaluation Methodology of Chinese Circular Economy

The realization of circular economy is an ongoing and integrated process. Therefore, the evaluation of the development level of circular economy of a given region is actually a process of integrated evaluation of multiple indicators. In the practice of integrated evaluation, it is possible to use multiple methods to identify indicator weights, the common ones of which are methods such as Delphi method, level analysis, pairing factors comparison and statistical analysis. Ms. Yu Liying and Feng Zhijun (2005) choos a kind of subjective value assignment methodology. The commonly used subjective value assignment method is Delphi method, also referred to as expert opinion consultation method. In practice, to determine the weight of an indicator, it is possible to consult with a number of experts and make an integrated treatment of feedbacks and then return the results to the experts again and again till all experts reach consensus as to the weights of the indicators [11]. Mr. Xiang Laisheng (2007) selects the subjective value assignment method, which is typically represented by the method of level analysis. It is a method of decision-making analysis combining quality and quality. Decision-makers can separate a complex issue into a number of levels and factors and make simple comparisons and calculations among variable factors so as to obtain indicator weights [17]. Scholars like Mr. Tian Jingfan (2007) proposes that it is necessary to determine the indicator weights by using principal component analysis so as to avoid the subjectivity of weight determination as assumed, thus obtaining a model of integrated evaluation of circular economy. The principal component analysis is to identify a few lesser complex indicators from multiple indicators, which can better reflect the information of original materials by using the idea of dimensionality reduction [18]. Mr. Pang Qinghua (2012) studies the setup of evaluation indicators system of circular economy regarding enterprise performance, holding that its external performance should be multidimensional, with its polyphyletic targets. Therefore, it is a multilevel integrated evaluation with multiple factors and many targets. It is important that the fuzzy theory be combined with the level analysis method to build a mathematical model of fuzzy integrated evaluation, which can be employed to make a quantitative assessment of enterprise performance [19]. Ms. Fen Yan (2007) proposes the adoption of subjective value assignment method, of which difference actuation method is used to identify indicator weights, thus ensuring the value assignment of weight is not affected by man-made subjective factors. As a technical method, correlation method is used to analyze the correlations of various factors in a system. Basically, it is possible to judge the correlation extent according to the similarity extent among curves. The high correlation indicates that there is basic consistency in relative change between the two. On the contrary, it shows that there is big variation among the two. Gray relational analysis can not only make a vertical comparison analysis of the construction of circular economy in different periods to assess the completion effects and standard achievement of program objectives, but also make a horizontal comparison analysis of the construction of circular economy in different regions [20].

4. Evaluation Comparative Analysis of Circular Economies at Home & Abroad

With the constant deepening of circular economy in the international and national practices, measuring development level in this regard has become an important field of the research of circular economy. As we know, many scholars have conducted numerous researches on the evaluation of circular economy from different perspectives. It can be found from the integration of foreign and domestic researches that although China began the research on circular economy early, but the theoretical researches on economic development modes are still in the explorative stage, currently focusing on the application in specific fields and the research on implementation instruments, most of which are based on their realities. For example, the DuPont mode in the USA and the unit doublet recovery system mode in Germany lack a systematic theoretical leap. The widespread application of MFA method requires a foundation of systematical material flow information, in practice, there has been a lack of data in this connection, thus to certain extent restricting the application and development prospect of the method. The researches on circular economy in our country are mainly concentrated in the discussion of fundamental theories and implementation instruments. There has been basic consistency between evaluation methods of circular economy and indicators evaluation methods of other fields, but there has been a lack of researches on method improvement of circular economy. Although many scholars have carried out relevant studies on the evaluation of circular economy, there exist some issues which need to be constantly improved in the later exploration of theories and practices. They are as follows:

(a) There have been less research outcomes as to evaluation indicators system and evaluation methodology regarding circular economy system, while there have been more researches on evaluation indicators system concentrated in individual case studies, but there has been a lack of a set of widely applicable evaluation indicators system of circular economy. Worse still, researchers are generally content with giving a wide range of indicators to develop an indicators system, with inadequate explanation of the internal relationship between the indicators and circular economy, whether inevitable or occasional. It is closely associated with their differences in knowledge level, background, review perspective, values, in particular, understanding of objectives.
(b) Indicators are too complex and unbalanced. Various types of indicators vary in the effects over circular economy development and impact extent. In the selection of indicators, researchers make a detailed list of a wide range of possible indicators that are too complex and unbalanced; with much less dynamic indicators that reflect the development of circular economy.
(c) For the evaluation of circular economy development, it mainly employs the traditional evaluation method like level analysis. Although it is highly applicable to the decision-making and evaluation with many targets, multiple factors and multi-levels, its accuracy is to some extent affected by man-made factors since the selected method for determining indicator weights is the qualitative and quantitative combination.
(d) There has been a shortage of data sources and inconsistency in statistical methods. Due to the complexity and integrity of evaluation indicators system, there is a need to have multiple data to support the rationality and feasibility of selected indicators, hence the importance of data sources. Presently, due to the shortage of data sources, some important data have resort to estimation. In addition, as a result of different types and characteristics of statistical indicators, there is some inconsistency as to the current statistical methods.
(e) There has been a lack of demonstration for testing the rationality of indicators system. It is not common to find the research outcomes that integrate indicators establishment, evaluation models and empirical research into one. Therefore, it is hard to apply indicators systems into practice, many of which only are confined to the theoretical discussion in the academic world.
(f) More research focus is on evaluation indicators system at the social level, while

less research focus is on that at the enterprise level. The research on industrial correlation or potential correlation among core industries and all kinds of industry or among enterprises is significant. However, in this regard, relevant studies in China are still confined to the design of parks, and the evaluation indicators for core enterprises and their industrial correlations in the parks are still imperfect.

Chapter III Design of Evaluation Indicators System of Circular Economy

I. Design Principles for Evaluation Indicators System of Circular Economy

1. Review of Foreign and Domestic Literatures

Up to now, developed nations like the USA, Germany and Japan have already obtained certain social benefits in the practices of circular economy development. It has been increasingly recognized that circular economy is an inedible choice for the realization of sustainable development. Thus other countries or regions have begun to follow their steps to include circular economy development as part of their actual operations. In preparing general plans and regional, urban and special plans, they place the development of circular economy in the important strategic position.

The international researches on the evaluation indicators system of circular economy are concentrated in the 1990s, broadly in the four aspects as follows: firstly, based on the existing evaluation indicators system of social development, the new types of indicators that can embody the idea of circular economy are developed; secondly, an indicators system of sustainable development is constructed; thirdly, an evaluation indicators system of circular economy is based on material flow analysis; fourthly, it is necessary to research on the evaluation indicators system of circular economy in terms of ecological efficiency.

The national researches on the evaluation indicators system of regional circular economy are concentrated at the three levels as the following: first, at the enterprise level, second, at the industrial park level, third, at the regional level. The researches on the system at the social level are rich, while the researches on the system at the industrial park and enterprise levels are relatively inadequate.

From the perspective of evolution process, at home and abroad, integrated evaluation of circular economy has been constantly evolving with social, economic and environmental changes in all historical periods. Circular economy developed is designed to achieve the mutual coordination between economic growth as well as resource, the environment and ecology, that is, the realization of maximum of economic and social benefits by using the minimum resource consumption and the minimum environmental price. The establishment of evaluation indicators system of circular economy helps the government as a macroeconomic regulator to formulate the objectives, plans and strategies of circular economy at the level of macro-management, and make judgment over the operational performance and development level regarding circular economy. Therefore, according to local realities and implications and ideas of circular economy, it is important to construct a rational evaluation indicators system of circular economy, thus providing theoretical basis and reference indicators for developing the plans, objectives and concrete measures of circular economy. It can also provide a quantitative evaluation tool for supervising, assess and evaluate the effects of circular economy development, so that the government can not only play a role of policy orientation, but also provide detailed technical indicators and parameters in the macro regulation and management. In such a way, the development of circular economy can be ensured to have a scientific basis.

2. Design Principles for Indicators System

As for the selection of evaluation indicators of circular economy development, it is advisable to consider economic, environmental, ecological and social factors in order to constitute a complete and overall indicators system. The selection of indicators has to comply with the criteria as follows: [21].

(a) Adhering to the 3R principles. The indicators system of circular economy development is, in essence, to reflect the application status and implementation results of the 3R principles of circular economy, thus the selection must highlight the core status and important role of the 3R principles in the whole indicators system.
(b) Combining levels with systems. Circular economy development is characterized by vivid levels and complex systems. For a given country, it has different levels such as region, city, sector and enterprise. For a complex system, it has multiple subsystems in the economical, ecological, environmental and social aspects and each subsystem has its own specific levels. Therefore, evaluation indicators system should engage both levels and systems.
(c) Combining integrality with relativity. Circular economy development is a complex systematical project, with its indicators system is an organic body, so the selection of indicators not only considers separating it into different subsystems showing the major characteristics and situation of the system being evaluated from different perspectives, but also requires taking many aspects like ecological environment and socioeconomic development in consideration as a whole from the perspective of the whole system of circular economy development.
(d) Combining level indicator with structural indicator. The level indicator, also referred to as an absolute factor, is used to indicate the total size and level of an socioeconomic phenomenon, whereas the structural indicator, also known as a relative indicator, is commonly used to show the amount correlations among socioeconomic phenomena. The singular use of the level indicator or the structural indicator has its disadvantages, so it is better to combine both of them in an effective manner to deeply and completely reflect the current development situation of circular economy.
(e) Combining static indictor with dynamic indicator. The establishment of an evaluation indicators system of circular economy development is meant not only to evaluate the development of circular economy, more importantly, and to make prediction of future trends of circular economy as well. Therefore, in the evaluation indicators system, it is important to have not only the static indictor showing the current scale and development level of circular economy, but also the dynamic indicator that comprehensively indicates the characteristics of dynamic changes as well as development trends of a circular economy system.
(f) Combining scientific rationality with realistic operability. The scientific rationality of indicator system is embodied by: various factors can highly abstract and summarize inputs and outputs relating to materials, fund and elements in all levels and links of the system of circular economy, thus revealing their natures, characteristics and relations, and the internal regular patterns observed in the process of operation. Meanwhile, what the indicators represent in the indicators system need to be brief and concise and consideration is given to the complexity or simplicity of such issues as quantification of indicators and acquisition of data, to improve the operability as far as possible.

(g) Combining comparability with reliability. The evaluation indicators system should have the functions of dynamic comparability and horizontal comparability. The dynamic comparability is a dynamic time-series comparison of development levels concerning circular economy in a given area; while the horizontal comparability refers to a permutation-related comparison of numerical values of comprehensive evaluation indicators at the same time in different regions, indicating the imbalance of circular economy development in the different regions. In the meanwhile, for the selection of statistical indicators, it is necessary to have explicit meaning and the same voice, to be consistent with international practices, to comply with international standards and the requirements of the current domestic statistical system so as to ensure the reliability of statistical data.

II. Design of Evaluation Indicators System of Circular Economy

1. Preliminary Selection of Indicators System

At present, the establishment of the evaluation indicators system of circular economy in the PRC is still at the research stage, without a set of well-established system of evaluation indicators. Therefore, it is essential to use currently ripe evaluation indicators systems for reference in order to construct a perfect system of indicators system. Meanwhile, the design of indicators system shall be carried out in accordance with the implications, objectives and principles of circular economy, giving serious consideration to various factors influencing development of circular economy. Additionally, based on the analysis of systematical structure and hierarchical structure and in combination with design principles of the system, it is wise to initially select concrete evaluation indicators to establish a preliminary evaluation indicators system.

In 2007, for the purposes of adequately implementing the document entitled the *State Council's Opinions on the Acceleration of Circular economy Development* (Reference No. Guofa [2005]22), scientifically evaluating the development of circular economy in China, providing the data-related support for the formulation and implementation of a development program of circular economy, promoting the circular economy development and building a resource-saving and environmentally-friendly society, the National Development and Reform Commission, the SEPA and the National Statistics Bureau jointly prepared and issued a document entitled the *Evaluation Indicators System of Circular economy*, which covers social level and industrial park level. The social level stipulates 22 evaluation indicators of circular economy, which are used to make overall quantitative judgment on the developments of circular economy in the whole society and different areas, thus providing a rationale for the formulation and implementation of a development program of circular economy. The indicator of resource output includes output rate of primary mineral resources output rate of energy. The indicator of resource consumption includes mainly consumption of GDP per unit, consumption of industrial added value per unit, comprehensive energy consumption per unit of primary products, water requirement of GDP per unit, water requirement of industrial added value per unit, water consumption of product per unit in priority sector and effective use efficiency of agricultural irrigation. The indicator of integrated use of resource includes integrated use rate of industrial solid waste, repetitive use rate of industrial water, renewable use rate of urban sewage, hazard-free treatment rate of urban living garbage, and recovery and use rates of rejected iron materials, rejected nonferrous metals, waste paper, waste plastics and waste rubber.

The indicator of wastes emission includes emissions of industrial solid waste, industrial waste water, sulfur dioxide and COD.

In 2013, to further promote the development of circular economy, the Qinghai Provincial Party Commission and the Qinghai Provincial Government issued a document entitled the *Action Plan of Constructing National Circular economy Pilot Zones in Qinghai* (Reference NO.: Qingfa [2013]20). The document points out that the construction of national circular economy development pilot zones is an important strategic initiative for transforming the approach of economic development, a strategic choice for realizing the sustainable development and a powerful instrument for enhancing the regional economic competitive capacity for Qinghai and therefore it is essential to set about constructing the recycle-oriented systems of heavy industry, agriculture, services and the society. To realistically reflect the development of circular economy, the documents also stipulate 22 primary indicators. Specifically, they include proportion of industrial added value of circular economy, improvement of output rate of primary resources, repetitive use rate of industrial water, integrated use rate of industrial solid wastes, proportion of renewable energy in energy production, proportion of ecological protection zones over national land area, quality of water environment, integrated consumption of electrolytic-aluminum-based alternating current, proportion of livestock added value in the primary industry, integrated use rate of crop straw, effective use coefficient of agricultural irrigation water, popularizing rate of methane or biogas, processing conversion rate of agricultural and livestock products, proportion of green buildings in the newly added civic building structures of the year, rate of collection, transportation and disposal of urban cooking wastes, contribution rate of science and technology to economic growth, proportion of research and development expense in main business income for big-size and medium-size enterprises and innovative enterprises, decrease in energy consumption of GDP per unit, emission of carbon dioxide, COD emission, emission of nitric oxide and emission of ammonia nitrogen.

Overall, the above indicators system focuses on the resource environment, but the highest goal of circular economy development is to realize the constant advance of human socioeconomic development under the condition of sustainable ecology. Circular economy is an integral body with multilateral coordination and comprehensive development that involves economy, society and resource environment, with its ultimate objective of achieving the win-win development of economy, society and resource environment. Mr. Yang Huafeng (2005) holds that circular economy is a systematical project that integrates economy, society and environment, dividing the evaluation indicators system of circular economy into 3 parts, namely, economic system, social system and ecological environmental systems [22]. Mr. Xi Yongqin (2003) contends in his *Research on Mechanism and Policy regarding Circular economy Development* that the current status of circular economy development is related not only to some indicators that can directly show the traits of circular economy development but also closely to the economic development and social development (including science &technology and education), thus having established a framework of four-level evaluation indicators system from the perspectives of subsystem of circular economy traits and subsystem of social and economic support [5].

The paper makes references to the above-mentioned evaluation indicators systems of circular economy, and reviews and collects available statistical materials, indicators and information at home and abroad, such as yearly books, handbooks, academic books, papers and reports. Based on the above, it attempts to create a system of general indicators regarding the evaluation of recycle development by employing such methods as frequency statistical method, theoretical analysis method and expert consulting analysis. The frequency statistical method is a method of making a frequent statistical analysis of the papers and reports regarding circular economy evaluation collected and selecting those indicators with high use frequency. The theoretical analysis method is a method of analyzing, comparing and integrating the connotations, traits and fundamental elements regarding circular economy and then selecting those indicators with great importance and pertinence. The expert consulting method is a method of initially proposing evaluation indicators and then consulting with experts or consultants for opinions or comments and eventually adjusting and refining the indicators.

2. Screening and Optimization of Indicators System

Although an indicators system is constructed in the process of preliminary selection, its scientific rationality and practicability are a basis and precondition for arriving at reliable conclusions. After the initial selection of indicators system, to ensure its scientific rationality, it is also essential to have a test of its scientific rationality, that is, the perfection treatment of preliminarily selected indicators, including individual test and overall test.

1) The individual test is used to test the feasibility and exactness of each indicator. The feasibility indicates the compliance of an individual indicator with the realities and the availability of indicator numeric values for analysis. The reliability analysis is an analysis of the exactness of calculation method, calculation scope calculation contents with respect to indicators.
2) The overall test is used to test the importance, necessity and integrity of the indicators of the system. The importance test is, according to regional characteristics, to make an analysis to determine which important indicators are kept and which indicators insignificant to evaluation results are ruled out. In general, the Delfi method is used to make an anonymous review of indicators system initially developed. The necessity test is used to holistically consider whether the evaluation indicators developed are essential and where they are redundant. The integrity test is used to examine whether the system of evaluation indicators can completely and adequately reflect the evaluation objectives and tasks described at an early stage.

After the optimal selection of evaluation indicators, it is also necessary to employ such methods as expert consulting method, principal component analysis method and independency method to carry out further screening of all obtained indicators. The expert consulting method is a method of first initially proposing evaluation indicators and then consulting with consultants or expert for opinions /comments and eventually adjusting and refining the indicators. The principal component analysis method is a polybasic statistical analysis method that, through appropriate mathematical conversion, reorganizes a series of indicators into a set of new unrelated comprehensive indicators for analysis. It can disclose information on the original indicators as much as possible. The independence analysis is used to test whether all indicators are relative, deleting some unnecessary indicators and simplifying the evaluation indicators system. Through the above screening, it is possible to select those relatively independent indicators with rich content, ultimately constituting a concrete evaluation indicators system of circular economy.

III. Overall Framework, Interpretations and Calculations of Evaluation Indicators System of Circular Economy

1. Overall Framework of Indicators System

The paper attempts to construct a four-level indicators system structure regarding integrated evaluation of circular economy development in terms of economic, social and resource-environmental systems. The structure consists of the four levels, namely, objective level, system level, criterion level and indicator level. Specifically,

1) Objective Level

Integrated evaluation of circular economy development has the overall objective of the coordinated development of economic, social, resource and environmental benefits in the mode of circular economy, with the objective level indicated by the system level.

2) System Level

Circular economy is a complex system, that is, an integrated strategy that integrates socioeconomic development, resource-saving and environmental protection. Therefore, it is possible to divide this big system into small subsystems in order to carry out evaluations. The review of large quantities of relevant foreign and domestic literature has contributed to separating the system of circular economy into 3 subsystems, namely, economical subsystem, social subsystem and resource-environmental subsystem. In such a way, it is possible not only to assess the integrated operation and development level of circular economy, coming to grips with the macro trend of circular economy, but also to evaluate each subsystem, getting informed of its operation situation.

3）Criterion Level

As each subsystem is established previously, it follows that it will be further subdivided. In the process of subdivision, there is a tendency to make an analysis from different perspectives. The economic subsystem can be split into two parts: level indicator and structural indicator. They can be used to show the total economic volume level and the economic structure level with respect to circular economy. It is necessary to disintegrate the social subsystem from the three perspectives of human settlement, social advance and scientific education. In the resource-environmental system, the basis is the 3R principles serving as the core part in the circular economy, like “volume reduction, Reuse and Resource-Recycling”. After the subdivision of the three subsystems, those indicators that have yet to be specific and measurable need to be further disintegrated.

3) Indicators Level

As the foundation level of the whole indicator system, all standards of the criterion are stated by specific indicators of the indicator level. The design of the level should choose those measurable, comparable, representative and highly independent indicators as evaluation indicators. In the meanwhile, it is important to use the available statistical indicators data as far as possible, thus allowing for saving resources, facilitating the collection of information and data, ensuring the reliability of data as well as achieving the objectives of integrated evaluation. In the paper, the indicator level consists of 32 indicators, with a concrete indicators framework as shown in Table 3-1.

Table 3-1 Evaluation Indicators System of Circular economy

Objective Level	System Level	Criterion Level	Indicator Level	Property
Development level of circular economy	Economic Subsystem	Economic Level	Regional GDP growth rate X1	
			Per capita regional GDP X2	
			Per capita governmental finance income X3	↑
			Per capita consumable goods retail sales X4	↑
		Economic Structure	GDP proportion of the tertiary industry added value X5	↑
			GDP proportion of social fixed assets investment X6	↑
			Urbanization level X7	↑
	Social System	Human Settlement	Per capita park green land area X8	↑
			Green coverage rate of constructed areas X9	↑
			Per capita urban road area X10	↑
			Private car ownership per thousand X11	↓
		Social Advance	Per capita controllable income of urban citizens X12	↑
			proportion of social security expenditure in finance expenditure X13	↑
			Proportion of medical treatment and health in finance expenditure X14	↑
			Bus ownership per thousand X15	↑
		SECP	Intensity of R&D grant input X16	↑
			Proportion of education in finance expenditure X17	↑
			Number of students on campus at higher institutions per 100,000 persons X18	↑
			Per capita culture & P.E. expenditure X19	↑
	R-E-S	Volume Reduction	Integrated energy consumption of GDP per unit X20	↓
			Power consumption of GDP per unit X21	↓
			Water consumption of GDP per unit X22	↓
			GDP proportion of Environment Management Investment X23	↑
			Waste water emission of GDP per unit X24	↓
			Chemical oxygen demand and emission of GDP per Unit X25	↓
			Ammonia nitrogen emission of GDP per unit X26	↓
			Sulfur Dioxide emission of GDP per unit X27	↓
			Nitric oxide emission of GDP per unit X28	↓
			Industrial solid waste generation of GDP per unit X29	↓
		Reuse & Recycling	Rural methane ownership per person X30	↑
			Repetitive use rate of urban industrial water X31	↑
			Capacity of daily treatment of urban sewage X32	↑
			Integrated use rate of industrial solid wastes X33	↑
			Concentrated treatment rate of urban living sewage X34	↑
			Hazard-free treatment rate of living garbage X35	↑

Notes: 1. SECP refers to Science, education, culture and P.E..
2. R-E-S stands for resource environmental subsystem.

2. Interpretation of Indicators

Regional GDP growth rate (%): By calculation according to different prices, the regional GDP growth rate of the year is converted into a value calculated by one base price to make the two values of different periods comparable, thus realistically reflecting variation scope. It is an important indicator used to show the dynamic change and development trend of economic level of a given area. The higher the indicator numeric value is, the more dynamic the economic development of the area is.

Per capita regional GDP (Yuan/person): It refers to a specific value of the regional GDP and the resident population of the area, that is, a regional GDP created by each resident citizen. It is one of the most commonly used and the most important macroeconomic indicators. It is used to measure the people's living level of a given area. The higher the indicator numeric value is, the better the economic development of the area, indicating that it is better able to provide a solid materials foundation for the development of circular economy.

Per capita governmental finance income (Yuan/person): it refers to a specific value of the total governmental finance income and the resident population of the area. There is interplay and independency between the governmental finance income and the economic growth in a given area, for a given area's economic development requires the backup of sufficient and stable governmental finance income. The per capita government finance income is extremely vital to the socioeconomic development and the improvement of people's living standard. The higher the indicator numeric value is, the greater sustainable development economic potential the area has.

Per capita consumable goods retail sales (Yuan/person): it refers to a specific value of social consumable goods retail sales and the resident population of the area. The social consumable goods retail sales is a sort of the most direct data showing domestic consumption demand, that is, an important indicator indicating the movement of domestic retail sales market and the status of economic prosperity. The per capita consumable goods retail sales is a reflection of the people's material and cultural living standards and the achievability of social purchase power of commodities.

GDP proportion of the tertiary industry added value (%): it refers to the proportion of the tertiary industry added value in the regional GDP. It is an indicator showing the optimization of industrial structure. The tertiary industry is an industry of low energy consumption and low pollution, including circulation agency and service agency. The higher the indicator numeric value is, the greater the development capacity of circular economy is and the more advanced the society is.

GDP proportion of social fixed assets investment (%): It is the proportion of social fixed assets investment in the regional GDP. It refers to the workload for constructing and procuring fixed assets expressed in a monetary form, which comprehensively reflects the scale and use orientation of fixed assets investment. The GDP proportion of social fixed assets investment is a structural indication that shows the relationship between speed and proportion with respect to fixed assets investment. The indicator can indicate the economic growth of a given area.

Urbanization level (%): it is the proportion of urban population of the total rural and urban population within a given area, which reflects the agglomeration process and agglomeration extent of urban population. It is an important indicator used to measure the economic development degree of the area. The higher the indicator numeric value is, the greater economic development potential and the stronger development driving force the area has.

Per capital park green land area (Square meters/per person): it refers to per capita occupation volume of green land area of urban parks. The urban park green lands are an important component of urban constructional land, urban green lands and urban municipal public facilities, so it is an important indicator that shows the overall level of city and the living quality of urban residents. The higher the indicator numeric value is, the better conditions the area enjoys and the more suitable the area is for people to live in.

Green coverage rate of constructed areas (%): It refers to a percentage of green coverage area of the constructed areas of the total constructed urban area. The green coverage area is the vertical projection plane of all vegetation plants such as arbor, shrub and lawn in a city. The higher green coverage area of constructed area shows that the area has the better green conditions and that it is more suitable for people to live in.

Per capita urban road area (square meters/per person): it is the road area owned per person for nonagricultural population in the urban area. The indicator can best and comprehensively reflect the smooth travelling level of a given area. The more the per capita urban road area is, the better the traffic situation of the area is and the more suitable it is for people's travelling and residence.

Private car ownership per thousand persons (vehicles/per thousand persons): it is a specific value of private car ownership and the resident population of the area. The popularity of private cars facilities the travelling of people, but with the rapid rise in private car ownership, there has a huge environmental and traffic pressure in the area. The greater the private car ownership per thousand persons is, the more severe negative impact it has over the human settlement environment.

Per capita controllable income of urban residents (yuan/per person): It refers to the total sum of ultimate consumption spending and saving of each resident on average, that is, the freely controllable income of urban residents. The indicator is considered the most important determinant in the consumption spending of urban residents, which is commonly used to measure the development of people's living level in a given area.

Proportion of social security expenditure in finance expenditure (%): it refers to the proportion of social security expenditure in the total expenditure of governmental finance. The social security expenditure is an expenditure of basic living security provided by the government through the form of finance to those social members with temporary or permanent loss of labor physical ability, loss of employment opportunity or significant living troubles or difficulties arising from various reasons. The bigger the proportion of social security expenditure in the total finance expenditure is, the higher the levels of social equity and social welfare are.

Proportion of medical treatment and health expenditure in finance expenditure (%): it is the proportion of medical treatment and health expenditure in the total finance expenditure. The medical treatment and health expenditure includes the expenditures in the aspects as follows: public health administration affairs, medical treatment services, medical security, disease prevention and control, public health supervision, maternity and child care and rural public health. The greater the proportion of medical treatment and health expenditure in the total finance expenditure, the higher level the levels of social welfare and social advancement are.

Bus ownership per thousand persons (vehicles/ per thousand persons): It is a specific value of bus ownership and the resident population of the area. Public transport, in particular, the rapid growth of buses, has increasingly played an important role in mitigating the urban traffic pressure, improving the urban residential environment and optimizing the means of people's travelling, thus to the great extent embodying the social advancement. The bigger the bus ownership per thousand is, the higher level the social advancement is.

Intensity of R&D grant input (%): It is a specific value of R&D grant expenditure of the whole society and the GDP of the area. It is a internally common core indicator that indicates the input level of science & technology of a given area. The high level of intensity of R&D grant input is regarded as an important assurance for improving the area's capacity of independent innovation. The stronger the capacity of independent innovation of a given area is, the better the area can rule out the out-of-date capacity with high input and high consumption and the stronger technical support the area can provide for the development of circular economy.

Proportion of Educational Expenditure in finance expenditure (%): It refers to the proportion of educational expenditure in the total finance expenditure. The educational expenditure covers the expenditures with respect to educational administration and management, preschool education, primary school education, junior middle school education, senior middle school education, general higher education, primary vocational education, two-year professional education, vocational school education, vocational high school education, higher vocational school, radio & TV education, international students education, special education, continuing education for adults, educational institutional services. The greater the proportion of educational expenditure in the total finance expenditure, the higher the levels of attention and input of the government in the education and talent development are.

The number of students on campus at higher institutions per 100,000 persons (students/per 100,000 persons): it refers to the average number of students on campus at higher institutions per 100,000 persons in a given area. The indicator can better reflect the development level of higher education of the area. The higher the indicator numeric value is, the higher level of higher education the area enjoys and the better it can provide a good foundation of talent support for the development of circular economy.

Per capita cultural and PE expenditure (Yuan/person): it refers to a specific value of cultural and PE expenditure in the total finance expenditure. It is used to measure the intensity of cultural and PE input, embodying the care for personal physical and mental health and to the great extent reflecting the social development and advancement. The bigger the per capita cultural and PE expenditure is, the more improved the development of a social system.

Integrated energy consumption of GDP per unit (ton of standard coal/per 10,000 yuan): It refers to the comprehensive energy consumption volume used up by the creation of regional GDP per unit in the reporting period in a given area. It is a major indicator that can show the level of energy consumption and the status of energy-saving and consumption-decreasing, thus better indicating the resource use extent of the given area's economic activities.

Power consumption of GDP per unit (Kilowatts per hour/per 10,000 yuan): It means the power consumption used up by the creation of regional GDP per unit in the reporting period in a given area. It is a major indicator that can show the level of power consumption and the status of energy-saving and consumption-decreasing, thus better indicating the power use extent of the given area's economic activities.

Water consumption of GDP per unit (Cubic meters/per 10,000 yuan): It means the water consumption used up by the creation of regional GDP per unit in the reporting period in a given area. It is a major indicator that can show the level of water resource consumption and the status of energy-saving and consumption-decreasing, thus better indicating the water resource use extent of the given area's economic activities.

GDP proportion of environmental management investment (%): It refers to the proportion of environmental pollution management investment in the regional GDP. The environmental pollution management investment covers the investments in rural environmental infrastructure construction, industrial pollution source management and environmental protection of the year's projects that have gone through the environmental protection acceptance procedure. The greater the GDP proportion of environment management investment is, the higher the levels of environment protection of a given area are.

Waste water emission of GDP per unit (tons/per 10,000 yuan): It means the total waste water emission required by the creation of regional GDP per unit in the reporting period in a given area. The lower the indicator numeric value is, the less the pollutant emission caused by a given economic activity, thus better complying with the principles of "volume reduction" regarding circular economy.

Chemical oxygen emission of GDP per unit (kilograms/per 10,000 yuan): It means the total COD emission required by the creation of regional GDP per unit in the reporting period in a given area. The lower the indicator numeric value is, the less the pollutant emission caused by a given economic activity is, thus better complying with the principles of "volume reduction" regarding circular economy.

Ammonia nitrogen emission of GDP per unit (kilograms/per 10,000 yuan): It means the total ammonia nitrogen emission required by the creation of regional GDP per unit in the reporting period in a given area. The lower the indicator numeric value is, the less the pollutant emission caused by a given economic activity is, thus better complying with the principles of "volume reduction" regarding circular economy.

Sulfur dioxide emission of GDP per unit (kilograms/per 10,000 yuan): It means the total sulfur dioxide emission required by the creation of regional GDP per unit in the reporting period in a given area. The lower the indicator numeric value is, the less the pollutant emission caused by a given economic activity is, thus better complying with the principles of "volume reduction" regarding circular economy.

Nitric oxide emission of GDP per unit (kilograms/per 10,000 yuan): It means the total nitric oxide emission required by the creation of regional GDP per unit in the reporting period in a given area. The lower the indicator numeric value is, the less the pollutant emission caused by a given economic activity is, thus better complying with the principles of "volume reduction" regarding circular economy.

Industrial solid wastes emission of GDP per unit (tons/per 10,000 yuan): It means the total industrial solid wastes emission required by the creation of regional GDP per unit in the reporting period in a given area. The lower the indicator numeric value is, the less the pollutant emission caused by a given economic activity is, thus better complying with the principles of "volume reduction" regarding circular economy.

Rural methane ownership per person (cubic meters/per person): It refers to the average methane ownership per rural resident. Methane is a renewable energy source with bright prospect of application, whose development and utilization not only can improve the situation of the shortage of rural energy supply, but also cannot have a negative impact over the environment. The higher the indicator numeric value is, the higher the rural renewable energy use rate is, thus better complying with the principle of "Reuse" of circular economy.

Repetitive use rate of urban industrial water (%): It refers to a specific value of repetitive use volume of urban industrial water in the total water use volume. The improvement of repetitive use rate of industrial water is one of the effective approaches of saving water, reducing pollution, improving the ecological environment and addressing the shortage of urban water, thus producing enormous social, social and ecological benefits. The bigger indicator numeric value shows the better compliance with the principle of "Reuse" of circular economy.

Capacity of daily treatment of urban sewage (10,000 cubic meters/per day): it is a capacity of daily treatment of the total urban sewage volume per day. On the one hand, the treatment of urban sewage can create a comfortable and clean living environment of people and address follow-up issues with respect to production. On the other hand, the technological upgrading of sewage treatment, through the renewable use, enables water resources to give full play to its potential value in the development of economy. The bigger indicator numeric value shows the better compliance with the principle of "Reuse" of circular economy.

Integrated use rate of industrial solid wastes (%): It is the proportion of integrated use volume of industrial solid wastes in the total generation volume of industrial solid wastes. The industrial solid wastes are of large quantities, multiple kinds and complex components, thus causing an enormous amount of environmental burden. Its integrated use is one of the effective approaches to environmental hazards, thus producing enormous social, social and ecological benefits. The higher indicator numeric value shows the better compliance with the principle of "Reuse" of circular economy.

Concentrated treatment rate of urban living sewage (%): it refers to a specific value of the living sewage volume up to the emission criterion after secondary or above treatment by urban sewage treatment plants and the total emission volume of urban living sewage. Urban sewage is characterized by big emission, concentration of places and complex kinds of pollutants so that its concentrated treatment can greatly resolve the issue of water pollution. The bigger the indicator numeric value is, the higher the levels of attention and input of the city in the concentrated treatment of urban sewage are.

Hazard-free treatment rate of living garbage (%): It is the proportion of the amount of hazard-free treatment of urban living garbage in the total generation volume of urban living garbage. The hazard-free treatment of living garbage can decrease the impact of garbage and its ramifications over the environment, reduce the emission of pollutants and achieve the resource recovery and use. The bigger the indicator numeric value is, the higher the levels of attention and input of the city in the hazard-free treatment of urban living garbage are.

3. Calculation of Indicators

As of the above system of indicators established, some data of indicators can be directly obtained; whereas others need to be indirectly obtained by simple mathematical operation. They can be obtained as follows:

1) Regional GDP growth rate is directly available in the *Statistical Bulletin on National Economy and Social Development* of the region;
2) Per capital regional GDP = regional GDP / resident population;
3) Per capital governmental finance income = total government finance income / resident population;
4) Per capita consumable good retail sales = social consumable goods retail sales / resident population;
5) GDP proportion of the tertiary industrial added value = the tertiary industrial added value / regional GDP;
6) GDP proportion of social fixed assets investment = social fixed assets investment / regional GDP;
7) Urbanization level = urban population / total urban and rural population;
8) Per capita park green land area = urban park green land area / urban nonagricultural population;
9) Green coverage rate of constructed areas = green coverage area of constructed areas /total land area of constructed areas;
10) Per capita urban road area = urban road area / urban nonagricultural population;
11) Private car ownership per 1000 persons = private car ownership / resident population;
12) Per capita controllable income of urban residents is directly available in the yearly statistics books of the area;
13) Proportion of social security expenditure in the governmental finance expenditure = social security expenditure / total governmental finance expenditure;
14) Medical treatment and health expenditure in the governmental finance expenditure

= medical treatment & health expenditure / total government finance expenditure;
15) Bus ownership per 1000 persons = bus ownership / resident population;
16) Intensity of R&D grant input = R&D grant expenditure of the whole society / regional GDP;
17) Proportion of educational expenditure in the finance expenditure = educational expenditure / total governmental finance expenditure;
18) Number of students on campus at higher institutions per 100,000 persons is directly available in the yearly statistics books;
19) Per capita cultural and PE expenditure = cultural & PE expenditure /total governmental finance expenditure;
20) Integrated energy consumption of GDP per unit = total integrated resource consumption volume / regional GDP;
21) Power consumption of GDP per unit = total power consumption volume / regional GDP;
22) Water consumption of GDP per unit = total water consumption volume / regional GDP;
23) GDP proportion of environmental management investment = expenditure of environmental management investment / regional GDP;
24) Waste water emission of GDP per unit = waste water emission / regional GDP;
25) Chemical Oxygen emission of GDP per unit = total COD emission volume / regional GDP;
26) Ammonia nitride emission of GDP per unit = total ammonia nitride emission volume / regional GDP;
27) Sulfur dioxide emission of GDP per unit = total sulfur dioxide emission volume / regional GDP;
28) Nitric oxide emission of GDP per unit = total nitric oxide volume / regional GDP;
29) Industrial solid wastes generation of GDP per unit = total generation volume of industrial solid wastes / regional GDP;
30) Rural methane ownership per person = total methane generation volume / urban population;
31) Repetitive use rate of urban industrial water = total repetitive use volume of industrial waste waters / total urban water use volume;
32) Capacity of daily treatment of urban sewage = total volume of urban sewage treatment / days of urban sewage treatments;
33) Integrated use rate of industrial solid wastes = integrated use volume of industrial solid wastes / total generation volume of industrial solid wastes;
34) Concentrated treatment rate of urban living sewage = concentrated treatment volume of urban living sewage / total emission volume of urban living sewage;
35) Hazard-free treatment rate of living garbage = hazard-free treatment volume of urban living garbage / total generation volume of urban living garbage;

The acquisition of the data on the indicators of integrated evaluation of circular economy development level has contributed to the issue of integrated evaluation of multiple indicators as analysis objects.

Chapter IV Selection & Improvement of Evaluation Methods of Circular Economy

I. Comparative Analysis of Common Evaluation Methods

1. Entropy Evaluation Method

The concept of entropy was first developed by German physicist Rudolf Clausius. It reveals the irreversibility of thermal transmission: heat energy tends to flow automatically from high temperature heat source to low temperature heat source instead of reverse flow. It is used to indicate a uniformity coefficient for the distribution of any given energy in space, in the sense that the more evenly the energy is distributed, the bigger its entropy is. The entropy evaluation method is a method of determining weights based on the differentials of indicator data among all programs. The concept of entropy was originally derived from thermodynamics and later introduced into the information theory by Claude Elwood Shannon. Nowadays, it has been extensively applied in the fields of engineering technology and socioeconomics. According to the fundamental law of the theory of information, information entropy is a measurement of information degree of disorder, while information is a measure of system orderly degree. The higher the orderly degree of a system is, the higher the information entropy is and the lower the information utility value is. As a result, it is possible to use utility value differentials of all indicators or entropy, by means of information entropy, to figure out their indicator weights, thus providing a basis for the integrated evaluation of multiple indicators. The method makes advantage of intrinsic information of evaluation indicators to determine their utility values, thus to some degree avoiding subjective deviation and objectively and accurately obtaining the weights of all indications in the evaluation indicators system of circular economy.

2. Data Envelopment Analysis (DEA) Method

Data envelopment analysis method is an evaluation method of systematical analysis developed based on the concept of “relative efficiency rating”. It is used to carry out a “sample quality” evaluation. It employs a mathematical programming method and use valid sample data observed to carry out a productivity evaluation of decision-making unit. It possesses particular input and out, thus trying to achieve of the goal of sustainable development of the system in the course of conversion of input into output. For the overall system of circular economy, the strong capacity of sustainable development means the use of less resource consumption and lower environment price to achieve greater social, social and resource environmental benefits. Expressed in the technical DEA terms, it goes as follows: resource and environment serves as “input” and economic and social development acts as “output”, thus its “relative efficiency” is used to measure the capacity of sustainable development of circular economy.

DEA is use to evaluate the technical and scale effectiveness of circular economy. In measuring the relative effectiveness of decision-making unit, each unit is optimized, in the sense that the unit with efficiency value of 1 is considered a relative efficiency unit. For the relative efficiency unit, it fulfills both technical effectiveness and scale effectiveness, showing that its resource-related allocation capacity and use efficiency is productive. For the non-efficiency unit, it is possible to use “law of projection” to indicate the adjustment orientation and scope of indicators and to make vertical time comparison and horizontal region comparison. It is also possible to make use of its basic functions to evaluate the capacity of sustainable development, thus providing a basis for the capacity construction of sustainable development of circular economy system, the shift from the unsustainable development to the sustainable development of the system, and the prediction, decision-making, coordination and control of the system.

3. Neural Network Analysis

Neural network is a complex network that is extensively connected by a large number of simple units. Neural network analysis can be described as, in analyzing a complex system, starting analysis from the lower level of units and gradually extending upward and eventually forming an analysis of the whole system. It extends by borrowing the scientific results of modern neurosciences. The analysis, by simulating a big number of essential functional and structural traits of biological neural system, makes use of nonlinear concurrent processing to mock numerous human brain nerve cells to process inputs. It has gained the successful application in the aspects of signal processing, mode identification, intelligent control and been gradually introduced into the integrated system evaluation.

The fundamental idea of neural network evaluation is as follows: To begin with, network starting points are assigned initial weight values; then each learning sample has to go through two transmission calculations in the network, specifically, one upward transmission calculation in which it is transmitted from the input level to different levels and after treatment an output is created, with an error value showing the difference between the output and the target output; and the other downward transmission calculation in which it is transmitted from the output level to the input level and the weigh values are revised level by level by using the error value. For the integrated evaluation of the development level of circular economy, any indicator can be taken as a starting point of neural network to go through the established network system for transmission processing and validation and eventually obtain the evaluation results of the overall system.

4. Integrated Fuzzy Evaluation Method

Integrated fuzzy evaluation is a method of carrying out integrated evaluation by applying the law of fuzzy relation synthesis to quantify some boundary-obscure boundary and unquantifiable factors based on the fuzzy mathematics. It is an evaluation method based on the fuzzy set, with its feature of having the evaluation method very close to one’s normal thinking modes and using degree language to describe evaluation objects. In the process of judging determinants, it is difficult to make explicit demarcation of many fuzzy phenomena, for example, social benefits and positive effects regarding circular economy and there is no effective way of describe them using common simple numbers. Therefore, it is inevitable to use fuzzy mathematics to reckon with them. Its mathematics law starts by considering that the determination of numeric values affecting the integrated evaluation of circular economy is fuzzy, that is, after determining an integrated evaluation indicators system of circular economy, all indicators that are not directly quantifiable shall not be treated quantitatively, but evaluators make fuzzy selection of the indicator criteria of various factors and then make a list of selection results of indicators system of evaluation factors by the expert panel, and carry out final calculations according to the already established mathematical model. The process of fuzzy evaluation method can be concluded by starting with qualitative fuzzy selection and carrying out mathematic operation according to the law of fuzzy conversion to obtain final results.

5. Principal Component Analysis (PCA)

As all indicators in the evaluation indicators system of circular economy are complex and closely related, there are high correlations among them, with overlapping information shown. Moreover, since multiple indicators increase the complexity of problem analysis, it is necessary to screen and simplify the indicators system and identify its major influencing factors.

Hotelling first developed the principal component analysis (PCA) in 1993. It is a widely used polybasic statistical analysis method of manipulating a complicated issue of multiple indicators, making it easier to analyze insidious influencing factors and compare the important degrees of indicators. Based on actual performance values of evaluation indicators of circular economy, it relies on numeric values of indicators to carry out an analysis of data, with the determination of indicator weights being less affected by unnatural factors, thus enabling the evaluation of circular economy to possess its high objectivity and credibility.

This method can be described as using the idea of dimensional decrease to reduce multiple factors to a few comprehensive indicators, with a small part of information of original indicators lost, thus not affecting evaluation results. Those comprehensive indicators are what we call the principal components that are independent of each other, with their numbers much less than the number of original variables and each of them being the linear combination of original variable. Consequently, when facing a complex issue of multiple indicators, it does not hurt to consider only a small number of comprehensive indicators to simplification, meanwhile, the result of evaluation will not be affected, thus improving the speed and efficiency of problem analysis. It is an effective simple and easy method of integrated evaluation in many fields.

II. Improvement of Evaluation Methods of Circular Economy Development

1. Necessity of Improvement of Evaluation Methods

The above methods have their own advantages and disadvantages. For example, the entropy evaluation method and the Neural network method, as typical objective weights assignment methods, make use of much improved mathematical theories and methods, and original information of vale assignments derives from the objective environment, but they neglect subjective information of decision-makers. The DEA method has a big advantage in the comparative analysis of many inputs and many outputs carried out the departments (decision-making units) of the same character. However, there exist some inadequacies such as only same type comparability, strong sensitivity to abnormal values and the tendency to have mere macroscopic implications. The fuzzy evaluation method tends to inevitably make “white” information fuzzy in the process of determining subordinate functions of indicators, thus causing some error of evaluation. Although the traditional PCA method can effectively simplify an evaluation indicators system, but only make an analysis of its static section data instead of dynamic panel data featured by time sequence. In order to avoid the disadvantages of the available evaluation methods, improve the scientific rationality and convenience of evaluation models and obtain well-rounded, scientific and accurate evaluation results, it is advisable to select an appropriate evaluation method in accordance with specific evaluation objects, the environment and objectives, while making some improvement in the method of selection.

2. Improvement in the PCA Method – Global PCA Method

Evaluation indicators system of circular economy is a huge system which covers 3 subsystems: economical, social and resource-environmental and consists of 4 levels, namely, objective level, criterion level and indicator level. It is characterized by numerous indicators and hot issues with complex relations among indicators. Here it is useful to select the PCA method in an attempt to objectively and accurately integrated evaluation results of circular economy. In the meanwhile, it is inevitable to consider the weakness that the traditional PCA method cannot make an analysis of dynamic panel data with time sequence but only can separate the panel data into a number of section data according to different hours for analysis. As a result, there should be some improvement, that is, using the global PCA method can effectively tackle the above-mentioned weakness.

The Global PCA method can apply the law of PCA to time series data sheet, unify the data of different hours on the same main plane and extract global principal components by linear changes. Therefore, there are the same composition of principal components of different hours and the same main plane consisting of principal component. Based on the above, it is possible to carry out a contrastive analysis of identical sample results of different hours, thus reflect the traits of dynamic changes of the samples.

3. Construction of Evaluation Model

Suppose that there is a time series vertical data sheet that is arranged by T section data sheets with sample points and indicator variables of identical names, expressed in the formula: $K=\{X^t \in R^{n\times p},\ t=1,2,\cdots,T\}$, with $e_1,\ e_2,\cdots,\ e_n$ and $x_1,x_2,\cdots x_p$ respectively showing n identical name samples and p identical name indicator variables in the time series vertical data sheets, that is, on each section data sheet in the time series cubic data sheet, x^t uses $e_1,\ e_2,\cdots,\ e_n$ as sample points and $x_1,x_2,\cdots x_p$ as invariable indicators.

In the x^t of T hours section data sheets, values for sample points such as $e_1,\ e_2,\cdots,\ e_n$ are respectively $e_1^t,e_2^t,\cdots,e_n^t$, then sample group points of t hours are $N_i^t=\{e_i^t,\ i=1,2,\cdots,n\}$, while global sample group points are $N_i=\cup_{i=1}^{T}N_i^t$.

Similarly, the above methods are used to make the same treatment of variables $x_1,x_2,\cdots x_p$, thus obtaining global data sheets of variable set X, $X=(x_{ij}^t)_{T_{n\times p}}$, its core definition shall be described as: in

$$g = \left(\overline{x_1}, \overline{x_2}, \cdots, \overline{x_p}\right)' = \sum_{t=1}^{T} \sum_{i=1}^{n} p_i^t e_i^t \qquad (1)$$

formula （1）， p_i^t is the weight of e_i of T hours sample points, and meeting the following requirement:

$$\sum_{t=1}^{T} \sum_{i=1}^{n} p_i^t = 1, \sum_{i=1}^{n} p_i^t = 1/T \qquad (2)$$

Then global variable is indicated as x_j ， then：

$$x_j = \left(x_{1j}^1, \cdots, x_{nj}^1, x_{1j}^2, \cdots, x_{nj}^2, \cdots, x_{1j}^T, \cdots, x_{nj}^T\right) \in R^{Tn} \qquad (3)$$

It can be seen from the general principle of mathematical statistics that global variance s_j^2 and global covariance S_{jk} are expressed as follows：

$$s_j^2 = Var(x_j) = \sum_{i=1}^{T} \sum_{i=1}^{n} p_i^t (x_{ij}^t - \overline{x_j})^2 \qquad (4)$$

$$S_{jk} = Cov(x_j, x_k) = \sum_{t=1}^{T} \sum_{i=1}^{t} p_i^t (x_{ij}^t - \overline{x_j})(x_{ij}^t - \overline{x_k}) \qquad (5)$$

Thus, constituting a global covariance matrix:

$$V = (S_{jk})_{p \times p} = \sum_{t=1}^{T} \sum_{i=1}^{n} p_i^t (_i^t - g)(_i^t - g)' \qquad (6)$$

After defining relevant concepts of global analysis, it follows that there will be a brief introduction on the fundamental principle of global principal components. The key to global principal component analysis lies in finding a global principal hyperplane $H + L$ wih many dimensions (M<P) by coordinate transformation and rotation movement of P dimensional global sample group points (horizontal transformation and rotating transformation), thus enabling e_i^t of global sample group points to have the minimum integrated difference between the project e_i^t on its top and original e_i^t, the is, meeting the least square principle. The global principal hyperplane obtained following the least square principle inevitably passes through the core of N_i and the standard orthogonal basis of the best conversion L obtained is $u_1, u_2, \cdots, u_m$ ($u_k M u_j = 1(j = k) / 0(j \neq k)$), corresponding to M characteristic values of VM such as $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_m$, here call $u_1, u_2, \cdots, u_m$ as the global principal axis. It is a director of new variables, while V and M are respectively global covariance matrix and measure matrix. Then one can obtain the following expression:

$$F_h(t,i) = (e_i^t - g)' M u_h \qquad (7)$$

$$F_h = \left[F_h(1,1), \cdots, F_h(1,n), \cdots, F_h(T,1), \cdots, F_h(T,n)\right]' \in R^{Th} \qquad (8)$$

It is possible to refer to F_h as the global principal component of No. h, as it is formed by the projection of sample group points N_i on the h principal axis. The global PCA is essentially an analysis of traditional PCA of time series data, and then it is inevitable to inherit good qualities of the traditional principle component analysis.

Firstly, global principal components must correspond to the maximum orientation of data variation. According to the law of traditional principal component analysis, it can be seen that to have the minimum integrated difference between the project e_i^t of original data $\{e_i^t, i = 1,2,\cdots,n, t = 1,2,\cdots,T\}$ on the global principle axis and original values will inevitably require that the global principal axis can be determined by the orientation of variation extent of data variance, and then rely on the projection of primary data on the global principal axis to extract the global principal components. consequently, the first principal component （F_1） will surely correspond to the first global principal axis with the maximum variation of distribution variance of data points; the second principal component（F_2） will certainly correspond to the second global principal axis with the secondary variation of distribution variance of data points. For other integrated variable orientations, they can be determined by inference alike, that is:

$$Var(F_1) \geq Var(F_2) \geq \cdots \geq Var(F_m) \qquad (9)$$

Secondly, global principal component is the best integration of original variables system. In the global principal component, if a comprehensive variable can perfectly take the place of all global variables $x_j, j = 1,2,\cdots, p$ of global data sheet, then it must be the first global principal component, for it contains the most information of original global variables. In other words, there is the maximum integration of correlation between global principal component F_1 and global variable x_j :

$$\sum_{j=1}^{p} r^2(F_1, x_j) \to \max \qquad (10)$$

For main hyperplane of M dimensions, it is possible to achieve the maximum integration of correlation between $F_h (h = 1,2,\cdots,m)$ and accumulated correlation of all x_j :

$$\sum_{h=1}^{m} \sum_{j=1}^{p} r^2(F_h, x_j) \to \max \qquad (11)$$

4. Steps of Evaluation Model

The use of the global PCA method for the evaluation of development level of circular economy can be made by the following steps achieved by a set of statistics software called “SPSS”: (a) establishing a global data sheet unfolding time series vertical data sheets in order of time sequence. It is the key difference between global PCA and the traditional PCA; (b) making a pretreatment of data in the global data sheet in order to meet the requirements of the global PCA and carrying out a forward direction conversion of data of reverse indicators in the global data sheet, thus making a standardization treatment of all indicators data on the above basis to obtain a standardized data sheet; (c) calculating correlation coefficient matrix in the standardized data sheet; (d) working out characteristic roots of correlation coefficient matrix and their corresponding characteristic vectors, and figuring out individual contribution rate and accumulating contribution rate of latent roots; (e) identifying the number of global principal component in accordance with research requirements and the accumulated contribution of principal components; (f) according to characteristic roots and characteristic vectors, calculating factor loading matrix and computing sample scores in each of global principal components; and (g) conducting normalization processing of variance contribution rate of principal component by the accumulated contribution rate of principal component to obtain the expression of integrated score F and global component F_i and then working out an integrated score of sample.

Chapter V Empirical Analysis of Integrated Evaluation of Circular Economy

I. Data Acquisition and Pretreatment

1. Data Acquisition

In 2005, the Chaidamu Circular Economy Experimental Zone became one of the first 13 national circular economy industrial pilot parks. In 2008, the Xining (National) Economic & Technological Development Zone became one of the second circular economy pilot pars. Over time, Qinghai Province takes advantage of its own resource environment and gets fully informed of international and national development trends and scientifically judges its stage characteristics of socioeconomic development. On such basis, the province insists on taking the development of circular economy as a key hard-nut attack orientation to transform economic development mode and to realize the sustainable development and sharpen regional economic competitive capacity, thus striving for developing the province into a national circular economy development pilot zone. At present, for Qinghai province, since the planning and policy system is basically formed, industrial framework initially constructed, the industrial chain growingly extended, the demonstrative driving role is obviously played and the scientific support remarkable strengthened, the development of circular economy in the province has promoted from tentative exploration to scientific development stage.

In an effort to explore an effective approach to the development of circular economy and to a new breakthrough of circular economy development, it is essential to make an adequate analysis of its current status, thus identifying a general direction of the further development of circular economy. Therefore, it is of special importance to carry out an integrated evaluation of the development level of circular economy in Qinghai. Firstly, it is possible to have an accurate understanding of the current development level and future development trends of circular economy in the province. Secondly, it is helpful to provide a theoretical and realistic basis for formulating governmental planning policies and security measures. From the two perspectives of horizontal comparison and vertical horizontal comparison, there is a need to objectively and accurately assess the development level of circular economy in Qinghai Province.

Horizontal comparison: The seven ministries or commissions like the National Development and Reform Commission, the Ministry of Environment Protection and the Ministry of Science & Technology jointly organized and carried out the acceptance work of national circular economy pilot and demonstration agencies or units and issued a shortlist entitled List of Qualified National Circular Economy Pilot and Demonstration Agencies or Demonstration (Second Issue) in 2005. The thirteen provinces or municipalities such as Tianjin, Liaoning, Shanghai, Jiangsu, Anhui, Shandong, Hunan, Guangdong, Chongqing, Sichuan, Shanxi, Gansu and Qinghai as regions of high circular economy development in China, have go through the acceptance procedure of circular economy pilot zones. The horizontal comparison of development levels of circular economy in the 13 provinces or municipalities leads us to have an objective and accurate understanding of the current development situation of circular economy of Qinghai Province in the PRC.

Vertical comparison: the vertical time series dynamic change comparison of circular economy development in 13 provinces or municipalities during the period from 2010 to 2014 can not only allow for understanding the changing trends of circular economy development of Qinghai Province, but also for comparing the changing trends of circular economy development of different provinces or municipalities and thus finding out the current development situation of circular economy of Qinghai nationwide.

In accordance with the already established evaluation indicators system of circular economy, reference is made to *China Statistics Yearly Book (2011-2015), China Environmental Statistics Yearly Book (2011-2015)*, *China Environmental Yearly Book (2011-2015)*, *China Urban Statistics Book (2011-2015)*, *China Science & Technology Statistics Yearly Book (2011-2015), China Energy Statistics Book (2011-2015)* and other statistics books (2011-2015) issued by all provinces or municipalities so as to obtain original data (2010-2014) of relevant indicators.

2. Data Pretreatment

Prior to data analysis, it is generally necessary to undertake a pretreatment of data by using standardized data for analysis. Data standardization is also referred to as indexation of statistical data. Its standardization treatment includes the two aspects like data forward direction (positive) treatment and dimensionless treatment.

1) Forward direction treatment: The established evaluation indicators system of circular economy consists of indicators of different properties. For positive indicators, it is characterized by the bigger the indicator value is, the better it is, for negative indicators, it is characterized by the smaller the indicator value is, the better it is. Forward direction treatment (positive treatment) is meant to resolve the problem of directors of different properties. As the direct sum of indicators of different natures fails to reflect properly comprehensive results of varying effects, it is essential to consider changing properties of negative indicators, thus enabling all of the indicators to have the forward direction treatment of effects of integrated evaluation.

Forward direction indicators: They include regional GDP growth rate X1, per capita regional GDP X2, per capita governmental finance income X3, per capita consumable goods retail sales X4, GDP proportion of the tertiary industrial added value X5, GDP proportion of social fixed assets investment X6, urbanization level X7, per capita road area X8, green coverage rate of constructed areas X9, per capita urban road area X10, per capita controllable income of urban residents X12, proportion of social security expenditure in government finance expenditure X13, proportion of medical treatment and health expenditure in government finance expenditure X14, bus ownership per 1000 persons X15, Intensity of R&D grant input X16, proportion of educational expenditure in finance expenditure X17, Number of Students on campus at higher institutions per 100,000 persons X18, per capita cultural and PE expenditure X19, GDP proportion of environment management investment X23, rural methane ownership per person X30, repetitive use rate of urban industrial water X31, capacity of daily treatment of urban sewage X32, integrated use rate of industrial solid wastes X33, concentrated treatment rate of urban living sewage X34 and hazard-free treatment rate of living garbage X35.

Negative indicators: private cars ownership per 1000 persons X11, integrated energy consumption of GDP per unit X20, Power consumption of GDP per unit X21, water of GDP per unit X22, waste water emission of GDP per unit, chemical oxygen demand (COD) of GDP per unit X25, ammonia nitrogen emission of GDP per unit X26, sulfur dioxide emission of GDP per unit X27, nitric oxide emission of GDP per unit X28 and generation volume of industrial solid wastes of GDP per unit.

2) Dimensionless treatment: Different indicators tend to have different measuring units, thus there inevitably exist differences between different dimensions, resulting in a lack of comparability among different indicators. Dimensionless treatment of data of indicators, also known as specification of data, a method of eradicating dimensional effects of original variables through mathematical conversion. It is meant to primarily address the comparability of indicators.

As to the above two, differences in nature or measuring unit lead to no direct comparison among different indicators, therefore there is need to carry out forward direction treatment and dimensionless treatment of index data of each evaluation indicator. Commonly used methods of standardizing indicator data include methods like range transformation, linear scale conversion, vector normalization, standard sample conversion. They have their advantages and disadvantages. Here it is helpful to select range transformation method to deal with indicator data.

Assume that there are n evaluation indicators $f_j(1 \le j \le n)$, m objects to be evaluated $a_i(1 \le i \le m)$, then n indicator values of m objects to be evaluated constitute a matrix called $X = (x_{ij})_{m\times n}$ decision-making matrix. In the $X = (x_{ij})_{m\times n}$ decision matrix, as of forward direction indicators:

$$y_{ij} = \frac{x_{ij} - \min\limits_{1\le i\le m} x_{ij}}{\max\limits_{1\le i\le m} x_{ij} - \min\limits_{1\le i\le m} x_{ij}} (1 \le i \le m, 1 \le j \le n) \qquad (12)$$

As of negative indicators:

$$y_{ij} = \frac{\max\limits_{1\le i\le m} x_{ij} - x_{ij}}{\max\limits_{1\le i\le m} x_{ij} - \min\limits_{1\le i\le m} x_{ij}} (1 \le i \le m, 1 \le j \le n) \qquad (13)$$

The matrix of $Y = (y_{ij})_{m\times n}$ is known as standardization matrix of range transformation. A strength of range transformation method is that whether indicator values of the decision-making matrix of $X = (x_{ij})_{m\times n}$ are positive number or negative number, after range transformation, standardized indicators meet $0 \le y_{ij} \le 1$, and forward direction indicators and negative (reverse) indicators are changed into positive indicators, with the best value of 1 and the worst value of 0. Table 5-1 shows the standardization matrix obtained from forward direction treatment and dimensional pretreatment of indicator data in 2014.

Table 5-1 Standardization Matrix in 2014

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17
天津	0.824	1.000	0.807	0.746	0.483	0.419	0.847	0.245	0.347	0.780	0.000	0.359	0.091	0.058	0.931	0.770	0.708
辽宁	0.000	0.492	0.287	0.596	0.218	0.617	0.529	0.439	0.788	0.478	0.599	0.269	1.353	0.002	0.473	0.296	0.033
上海	0.235	0.900	1.000	1.000	1.000	0.000	1.000	0.000	0.644	0.022	0.793	1.000	0.255	0.000	1.000	1.000	0.283
江苏	0.569	0.704	0.398	0.683	0.395	0.394	0.491	0.724	1.000	0.871	0.384	0.464	0.000	0.333	0.397	0.632	0.690
安徽	0.667	0.101	0.064	0.099	0.000	0.804	0.156	0.602	0.881	0.548	0.997	0.112	0.580	1.000	0.028	0.418	0.485
山东	0.569	0.437	0.156	0.547	0.276	0.466	0.278	1.000	1.017	1.000	0.332	0.274	0.344	0.839	0.226	0.516	1.000
湖南	0.725	0.176	0.047	0.200	0.231	0.650	0.159	0.265	0.661	0.478	0.977	0.176	0.704	0.814	0.036	0.243	0.561
广东	0.392	0.470	0.302	0.579	0.463	0.134	0.549	0.918	0.898	0.551	0.477	0.383	0.049	0.835	0.526	0.576	0.914
重庆	1.000	0.272	0.235	0.314	0.388	0.614	0.374	0.990	0.831	0.000	0.911	0.124	1.000	0.556	0.300	0.263	0.294
四川	0.529	0.110	0.071	0.176	0.112	0.569	0.096	0.408	0.568	0.070	0.841	0.090	0.769	0.861	0.113	0.313	0.442
陕西	0.765	0.260	0.148	0.192	0.054	0.726	0.227	0.531	0.822	0.265	0.670	0.095	0.772	0.678	0.160	0.477	0.662
甘肃	0.608	0.000	0.000	0.000	0.293	0.910	0.000	0.561	0.000	0.033	1.000	0.000	0.939	0.711	0.000	0.164	0.469
青海	0.667	0.168	0.106	0.012	0.054	1.000	0.169	0.357	0.068	0.052	0.621	0.019	0.381	0.152	0.249	0.000	0.000

Table 5-1 Standardization Matrix in 2014 (Continued)

X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35
1.000	0.421	0.937	1.000	1.000	0.820	1.000	0.909	1.000	0.930	0.919	0.995	0.046	0.984	0.125	1.000	0.864	0.912
0.559	0.197	0.749	0.928	0.788	0.311	0.543	0.268	0.533	0.649	0.631	0.827	0.019	0.984	0.411	0.000	0.794	0.775
0.695	0.508	0.974	0.978	0.816	0.379	0.517	1.000	0.919	1.000	1.000	1.000	0.000	0.893	0.413	0.970	0.850	1.000
0.535	0.259	0.983	0.906	0.531	0.559	0.536	0.836	0.848	0.922	0.898	0.984	0.107	0.774	0.871	0.959	0.535	0.949
0.335	0.035	0.892	0.910	0.285	1.000	0.037	0.269	0.214	0.794	0.477	0.907	0.026	0.886	0.319	0.804	0.864	0.987
0.392	0.025	0.863	0.929	0.871	0.584	0.612	0.546	0.747	0.754	0.730	0.955	0.304	0.944	0.494	0.941	1.000	1.000
0.307	0.000	0.900	0.986	0.332	0.211	0.246	0.203	0.000	0.802	0.866	0.967	0.467	0.215	0.284	0.423	0.577	0.992
0.371	0.081	1.000	0.905	0.690	0.000	0.000	0.665	0.636	0.963	0.948	1.000	0.054	0.950	1.000	0.790	0.897	0.636
0.587	0.004	0.872	0.968	0.745	0.453	0.407	0.610	0.509	0.620	0.771	0.975	0.632	0.000	0.123	0.789	0.911	0.979
0.334	0.102	0.799	0.925	0.580	0.348	0.227	0.265	0.238	0.739	0.864	0.921	1.000	0.669	0.271	0.097	0.568	0.877
0.794	0.274	0.847	0.935	0.780	0.720	0.666	0.578	0.583	0.525	0.452	0.923	0.151	0.928	0.135	0.412	0.903	0.888
0.326	0.156	0.488	0.588	0.000	1.025	0.482	0.000	0.033	0.000	0.000	0.846	0.403	1.000	0.070	0.207	0.468	0.000
0.000	1.000	0.000	0.000	0.386	0.528	0.439	0.200	0.351	0.226	0.060	0.000	0.064	0.273	0.000	0.306	0.000	0.634

II. Evaluation Process and Results

1. Descriptive Statistics of Variables

The global sample standardization data sheets of (13×35)×5 after the pretreatment can be put into the polybasic statistical analysis software of SPSS19.0. Firstly, it is necessary to conduct KMO & Bartlett sphericity degree test of sample data in order to examine if the sample data are suitable for global principal component analysis. As test results (shown in Table 5-2) suggest, the numeric value of KMO statistical magnitude of inclined correlation among variables is 0.7778 and the result significance level of spherecity degree test is 0.000. Secondly, it can be learned according to KMO measuring criteria developed by Kaiser (1974) that the same data is suitable for global principal component analysis.

Table 5-2 Results of KMO & Bartlett Sphericity Test

KMO Value		0.778
Bartlett sphericity test	Chi-square statistical value	4351.134
	DOF	595
	Signifcance level	0.000

2. Selection of Characteristic Values & Identification of Principal Components

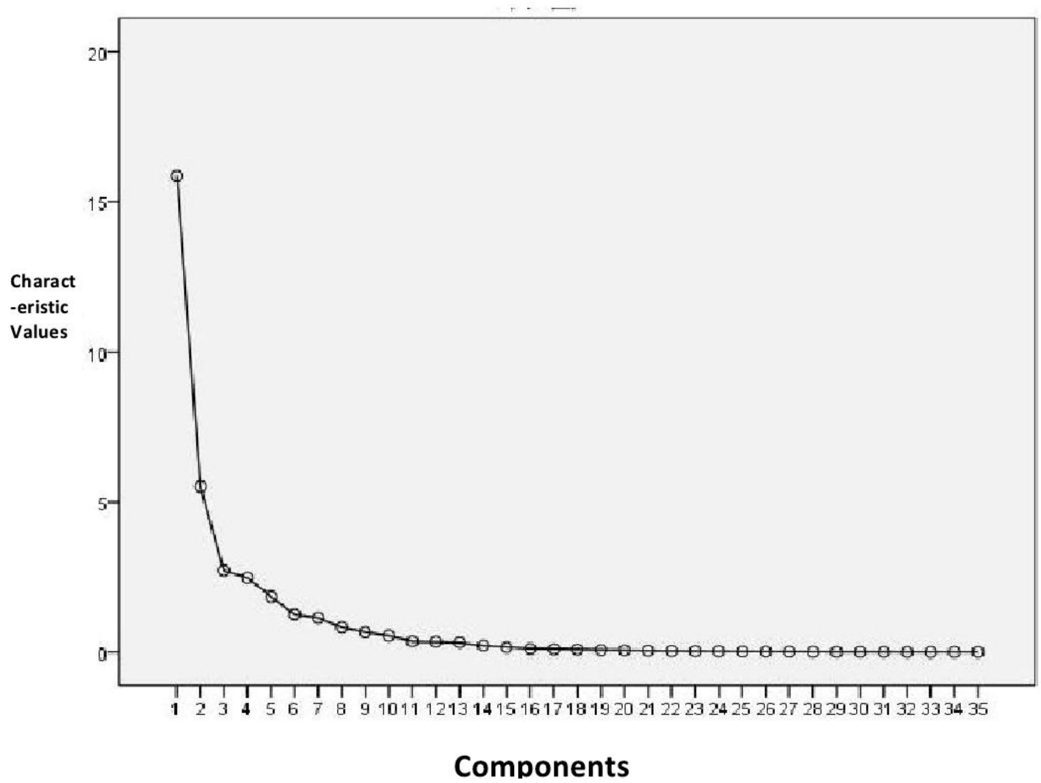
The software of SPSS19.0 is used to carry out the PCA and the maximum orthogonal rotation of variance of 35 variables to extract principal components according to the criterion that characteristic value is bigger than 1 and cumulative variance contribution rate is more than 85%. It can be seen from Table 5-3 that the characteristic values of the first seven components are 15.857, 5.521, 2.724, 2.481, 1.845, 1.260, 1.147 respectively and their cumulative contribution rate reaches 88.101%, bigger than 85%. Therefore, it is necessary to extract the seven global principal components as new comprehensive variables, expressed in F_1, F_2, F_3, F_4, F_5, F_6, F_7. In other words, it is possible to use global sample data sheet of （13×35）×5 to conduct global PCA by establishing 7 new comprehensive variables to replace 35 original indicator variables while reducing 28 indicator variables, thus having 80% of dimensional decrease range and good dimensional decrease effects. In a sense, it can condense the majority of information of original indicator data. Of course, it is also possible to draw the same conclusion from the Scree Plot (Graph 5-1).

If the characteristic values of the seven global principal components are substituted into $W_i = \lambda_i \Big/ \sum_{i=1}^{7} \lambda_i$ for the normalization treatment, then the effect weights of the seven global principal components over integrated score can be obtained. They are 0.514, 0.179, 0.088, 0.080, 0.060, 0.041 and 0.037 respectively. Eventually, one can have the following relation expression between integrated score and each principal component with respect to the development level of circular economy:

$$F = 0.514F_1 + 0.179F_2 + 0.088F_3 + 0.080F_4 + 0.060F_5 + 0.041F_6 + 0.037F_7 \quad (14)$$

Table 5-3 Characteristic Values, Contribution Rates and Cumulative Contribution Rates

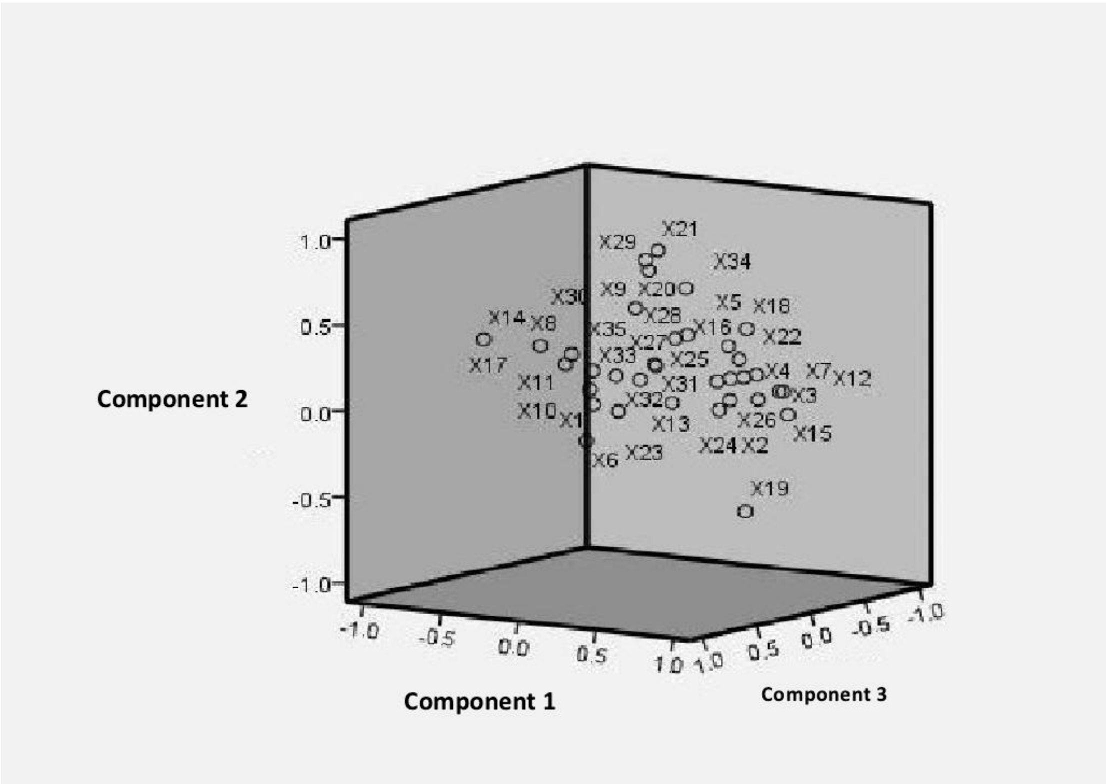
Compo	Initial characteristic values			Extracting quadratic sums and load			Rotating quadratic and load		
	Total	Variance %	Cumu. %	Total	Variance %	Cumu. %	Total	Variance %	Cumu. %
1	15.857	45.304	45.304	15.857	45.304	45.304	11.776	33.646	33.646
2	5.521	15.774	61.079	5.521	15.774	61.079	5.633	16.094	49.740
3	2.724	7.784	68.863	2.724	7.784	68.863	3.248	9.279	59.019
4	2.481	7.089	75.952	2.481	7.089	75.952	3.231	9.231	68.250
5	1.845	5.271	81.224	1.845	5.271	81.224	2.638	7.537	75.787
6	1.260	3.599	84.823	1.260	3.599	84.823	2.636	7.531	83.318
7	1.147	3.278	88.101	1.147	3.278	88.101	1.674	4.783	88.101
8	.829	2.368	90.469						
9	.669	1.913	92.382						
10	.556	1.588	93.969						
11	.367	1.048	95.018						
12	.351	1.002	96.020						
13	.325	.927	96.947						
14	.223	.637	97.585						
15	.166	.475	98.060						
16	.117	.335	98.395						
17	.104	.297	98.693						
18	.094	.269	98.962						
19	.075	.214	99.176						
20	.064	.184	99.360						
21	.049	.140	99.500						
22	.038	.108	99.608						
23	.031	.090	99.698						
24	.029	.082	99.780						
25	.019	.054	99.834						
26	.015	.044	99.878						
27	.012	.035	99.913						
28	.008	.023	99.936						
29	.006	.018	99.953						
30	.005	.013	99.967						
31	.004	.012	99.978						
32	.003	.008	99.986						
33	.002	.007	99.993						
34	.002	.005	99.998						
35	.001	.002	100.000						



Graph 5-1 Scree Plot

3. Determination of Principal Components and Integrated Scores

According to the load matrix of global principal components (Table 5-4), it is possible to obtain the relations among all principal components and all original indication variables. The variables such as X2， X3, X7, X15 are heavily uploaded on the principal component of F_1; the ones like X20, X21 and X29 are heavily uploaded on the principal component of F_2; the ones such as X13 and X33 have big upload absolute values on the principal component of F_3; the ones like X8 and X9 are heavily uploaded on the principal component of F_4; the ones such as X10, X24 and X31 are heavily uploaded on the principal component of F_5; the ones such as X1 and X32 have big upload absolute values on the principal component of F_6; and the one like X23 and X28 have big upload absolute values on the principal component of F_7. For the principal components such as F_1、F_2、F_3 and 3D coefficient of all indicator variables, it is possible to refer to Graph 5-2.



Graph 5-2 Components in the Rotating Space in the Areas

Table 5-4 Load Matrix of Global Principal Components

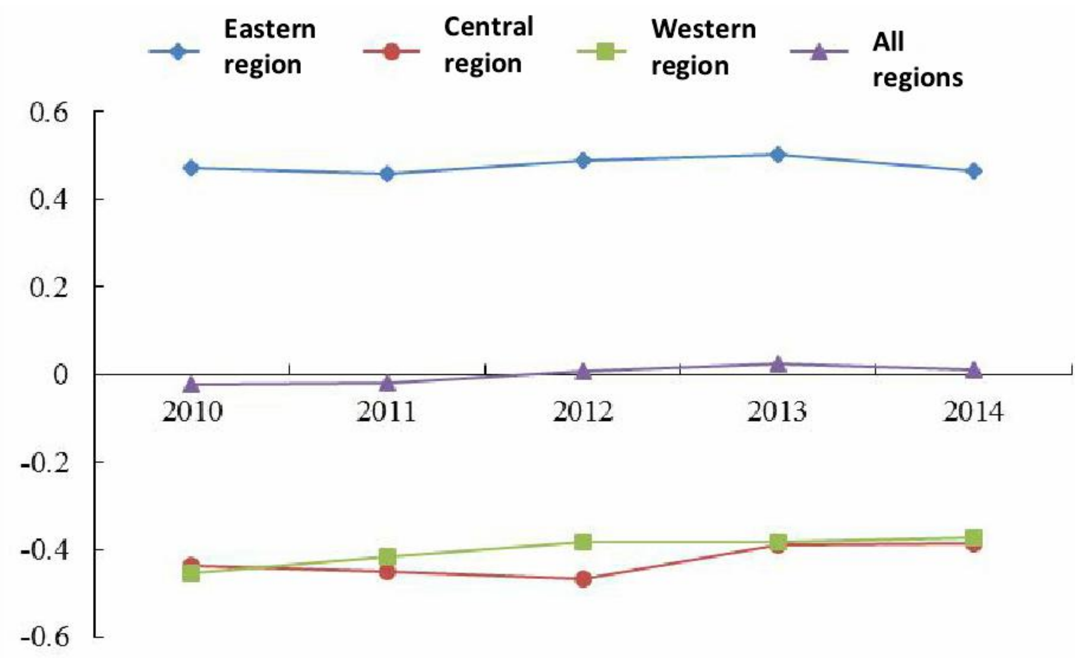
Var.	F_1	F_2	F_3	F_4	F_5	F_6	F_7
X1	-.285	-.038	.016	.142	-.060	-.849	-.108
X2	.905	.137	.193	.132	.259	.030	.112
X3	.971	.171	.054	-.055	.030	-.008	.072
X4	.859	.269	.142	.162	.196	.189	.152
X5	.745	.246	.219	-.239	-.114	.162	.144
X6	-.605	-.337	-.377	-.013	.097	-.363	-.295
X7	.955	.173	.071	.091	.061	.101	.055
X8	-.287	.233	.267	.663	.024	.103	-.352
X9	.055	.570	.111	.663	-.018	.358	-.026
X10	.018	.148	.480	.389	.612	.257	.061
X11	-.530	.084	-.329	-.327	-.623	.131	-.101
X12	.847	.267	.239	.003	-.054	.292	.118
X13	-.357	-.155	-.815	-.114	-.130	-.146	-.050
X14	-.796	.331	.301	-.228	-.032	-.016	.027
X15	.960	.025	-.005	-.013	.068	.109	.094
X16	.773	.447	.280	-.024	.228	.081	.062
X17	-.192	.403	.636	.076	.468	.100	-.064
X18	.677	.493	-.029	-.028	.327	-.338	-.039
X19	.635	-.579	-.077	-.265	.065	-.118	-.023

X20	.283	.844	.314	.168	.085	.155	.096
X21	.184	.919	.088	.201	.103	.022	.085
X22	.618	.307	-.044	.541	.305	-.132	.097
X23	-.116	-.058	.026	.004	.012	-.110	-.863
X24	.434	-.017	-.119	.039	.644	-.489	.005
X25	.770	.255	.381	.250	.100	.023	-.068
X26	.766	.128	.254	.373	.296	.055	-.077
X27	.481	.472	.352	.355	.029	.257	.310
X28	.478	.476	.235	.443	-.129	.136	.453
X29	.180	.877	.196	.041	.069	.014	.101
X30	-.534	.206	-.141	.088	-.321	-.397	.289
X31	.158	.252	.083	-.321	.749	.298	-.139
X32	.151	.234	.428	.283	.111	.727	.125
X33	.499	.284	.701	.210	-.037	.015	-.141
X34	.330	.703	.037	.400	.087	-.029	-.249
X35	.194	.250	.122	.731	-.039	-.260	.207

The software of SPSS19.0 is used to get scores of all principal components. The expression (14) can be employed to calculate the integrated scores of development level of circular economy in the provinces or municipalities in the period from 2010 to 2014 (see table 5-5).

Table 5-5 Integrated Scores of Development Level of Circular economy of 2010-2014 in the Provinces or Municipalities

	2010	2011	2012	2013	2014	Score chg	Ranking chg
Tianjin	0.776	0.839	0.882	0.885	0.866	0.090	2→2
Liaoning	0.058	0.078	0.139	0.150	0.130	0.072	6↑5
Shanghai	1.241	1.196	1.233	1.259	1.177	-0.064	1→1
Jiangsu	0.330	0.324	0.344	0.370	0.366	0.036	4↑3
Anhui	-0.446	-0.458	-0.522	-0.399	-0.377	0.069	11↑9
Shandong	0.061	0.023	0.049	0.069	0.030	-0.031	5↓6
Hunan	-0.426	-0.445	-0.412	-0.382	-0.398	0.028	10→10
Guangdon	0.361	0.282	0.285	0.287	0.220	-0.141	3↓4
Chongqin	-0.107	-0.026	0.011	-0.004	0.004	0.111	7→7
Sichuan	-0.402	-0.452	-0.419	-0.432	-0.402	0.000	9↓11
Shaanxi	-0.217	-0.118	-0.089	-0.082	-0.077	0.140	8→8
Gansu	-0.795	-0.856	-0.786	-0.761	-0.767	0.028	13→13
Qinghai	-0.743	-0.629	-0.625	-0.636	-0.629	0.114	12→12
Mean val.	-0.024	-0.019	0.007	0.025	0.011	0.035	—



Graph 5-3 Trends of Integrated Scores of Development Level of Recycle Development In the Areas

III. Empirical Results Analysis of Integrated Evaluation of Circular Economy

1. Overall Development Status

It can be learned from Table 5-5 that, over the period from 2010 to 2014, the mean values of integrated scores of circular economy development level in the 13 provinces or municipalities (integrated scores of circular economy development in all of the areas) went through a peak of wave from up to down. Specifically, the peak value was from -0.024 in 2010 to 0.025 in 2013, with an upward range of 0.049; after 2013, the integrated score was on the slow decrease, from 0.025 in 2013 to 0.011 in 2014, with a downward range of 0.013. Overall, over the period from 2010 to 2014, the integrated score went smooth; showing a slight increase, with an upward range of 0.035, and therefore it suggests that the circular economy in the provinces or municipalities had taken on a momentum of good development.

It can be seen from the regional distribution of calculation results that there exists a clear polybasic structure in development level of circular economy in the provinces or municipalities (see Graph 5-3). In terms of integrated scores of circular economy development, the eastern areas are far higher than the central and western areas; the western areas are slightly higher than the central areas, but both of them are obviously lower than the mean level of all of the areas. From the perspective of development trend, that is, the steep movement integrated score curve indicating circular economy development level of all of the areas, it can be learned that in recent years, the integrated scores of the eastern areas has been on the slow decrease, but those of the central and western areas have been on the constant rise. Overall, the discrepancy in circular economy development level among those areas has shown a good shrinking momentum.

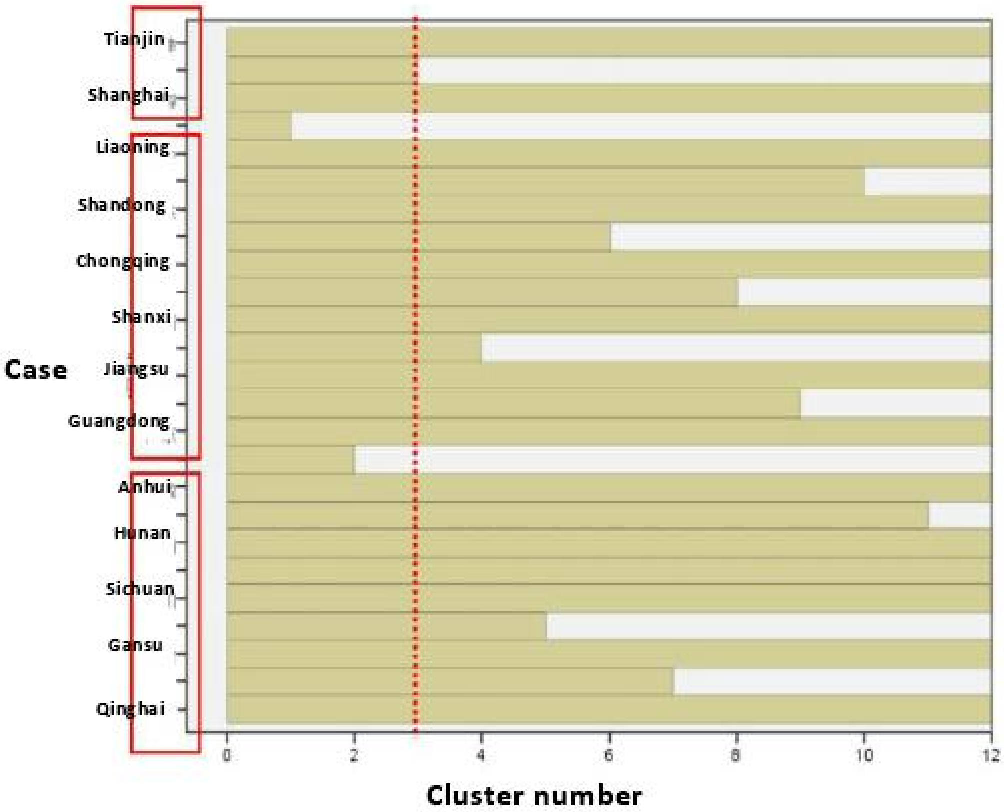
2. Development Levels of the Provinces or Municipalities

From the variation in the integrated scores of the provinces or municipalities (as showed in Table 5-5), the overall circular economy development level has shown a steady upward trend. Over the period from 2010 to 2014, nine of the 13 provinces or municipalities have been on the rise in terms of integrated scores, such as Tianjin, Liaoning, Jiangsu, Anhui, Hunan, Shaanxi, Gansu and Qinghai respectively, of which the rapid growth ones are Shaanxi, Qinghai and Chongqing, with an increase range of over 0.1. On the other hand, the decrease ones in terms of integrated scores are Shanghai, Shandong and Guangdong, of which Guangdong has the maximum decrease range of -0.141. It can be seen that the integrated scores of the western provinces or municipalities is overall on the rise. In contrast, the development momentum of circular economy in the western provinces or municipalities is much better than those of the eastern and central ones.

From the rankings of integrated scores of circular economy development levels of the provinces or municipalities (see Table 5-5), in 2010, the first five ones in the ranking list were Shanghai, Tianjin, Guangdong and Shandong, which were concentrated in the eastern areas; the lowest four ones were Huan, Anhui, Qinghai and Gansu, most ifo which were concentrated in the western areas. The above situation suggests that there exists a clear imbalance in space of circular economy development level. In 2014, the provinces or municipalities with unchanged rankings were Shanghai, Tianjin, Chongqing, Shaanxi, Hunan, Qinghai and Gansu; but Liaoning, Jiangsu and Anhui had upward rankings, of which Anhui had the maximum ascending range from the eleventh in 2010 to the ninth in 2014, with the other ones having an upward step; whereas there was a downward trend in terms of the rankings of Shandong, Guangdong and Sichuan, with Sichuan having a big descend range from the ninth to the eleventh and the other ones having a downward step. In 2014, the first six provinces or municipalities were Shanghai, Tianjin, Jiangsu, Guangdong, Liaoning and Shandong, which were mainly some eastern areas, but the western provinces like Sichuan, Qinghai and Gansu remained the lowest ones. Over the period of 2010-2014, the lopsided situation in space regarding circular economy development was not effectively mitigated, thus showing an apparent polybasic structure in space among the different areas.

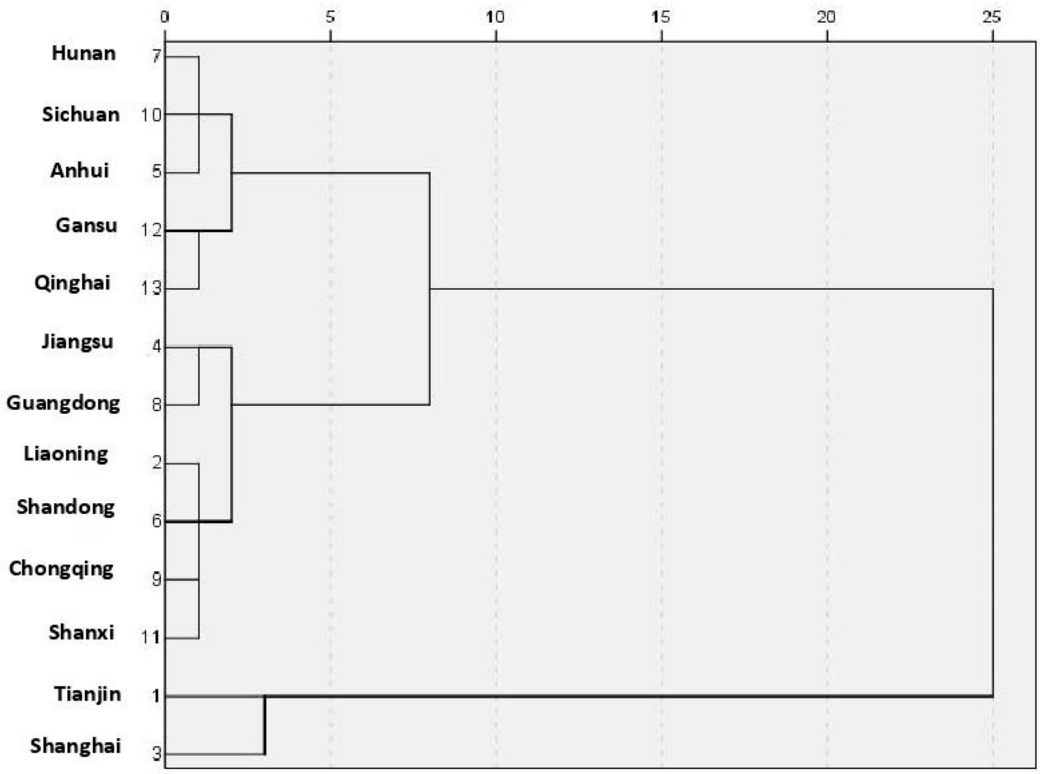
The software of SPSS19.0 is used to carry out a hierarchical cluster analysis of integrated scores of circular economy development level in the provinces or municipalities. The Icicle Graph (Graph 5-4) provides combined information from hierarchical cluster analysis including parts of overall cluster process or selected class number range. For the provinces or municipalities, when they are classified into 3 clusters, Tianjin and Shanghai are the first cluster, with high development level of circular economy; Liaoning, Shandong, Chongqing, Shanxi, Jiangsu and Guangdong are the second cluster, with intermediate development level of circular economy; and

Anhui, Hunan, Sichuan, Gansu and Qinghai are the third cluster, with relatively backward development and low level regarding circular economy.



Graph 5-4 Icicle of Hierarchical Clusters

The Tree Diagram (Graph 5-5), in the form of lying trees, exhibits cluster combination each time in the cluster analysis. SPSS can map automatically distances of all clusters over the range of 0 ～ 25, and approximately indicating the cluster process on the graph. Specifically, the first combined cluster includes Hunan, Sichuan and Anhui, the second cluster consists of Gansu and Qinghai; the third cluster covers Jiangsu and Guangdong; and the last one comprises Liaoning, Shandong and Shaanxi. By parity of reasoning, till all individual cases observed are combined into one cluster, inter-cluster distances at this point have grown exceptionally big. The results from both the Graph of Icicle and the Tree Diagram are coincidental and consistent, with the same cluster combination.



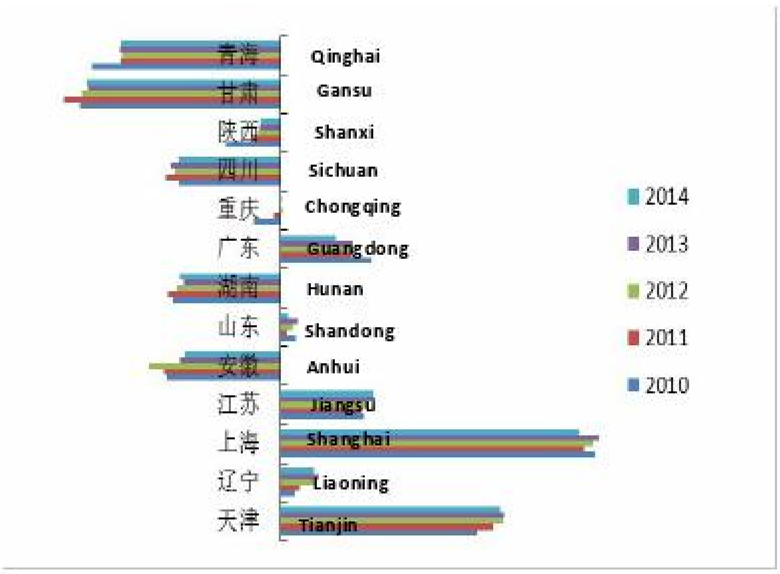
Graph 5-5 Tree Diagram of Hierarchical Clusters

3. Development Level of Qinghai Province

1) Horizontal Comparison

By horizontal comparison of the provinces or municipalities (see Graph 5-6), over the period from 2010 to 2014, for the integrated score of circular economy development level in Qinghai, it ranked the lowest in the thirteen provinces or municipalities and over time, such situation has shown no improvement, for there has been remarkable discrepancy in development level of circular economy between Qinghai Province and the eastern provinces or municipalities. In recent years, the eastern provinces or municipalities have been confronted with a succession of issues such as growing resource constraints, deteriorating environmental pollution and degraded ecological system. In an attempt to form a system of good spatial framework, industrial structure, and production and living modes of resource saving and environment protection, they insist on taking circular economy development as a primary task for transforming economic development approach. As early developed areas, the eastern provinces or municipalities have accumulated rich resources of financing, human talents and S&T and a great deal of development experience, with their mass and quality of socioeconomic development being far higher than that of the central and western ones.

In recent years, the development of circular economy in Qinghai has obtained considerable results. Qinghai Province boasts rich mineral resources of salt lake, petroleum and gas and nonferrous metals as well as abundant water, solar and wind energy resources. Additionally, other resources such as combustible ice (natural gas hydrate) and oil shale (kerogen shale) are found in the province. Such resources constitute unique advantages of circular economy development in Qinghai. Since the "Eleventh Five-Year Plan", the Qinghai Provincial Party Commission and the Qinghai Provincial Government have given full play to its unique advantages based on the provincial realities, taking the development of circular economy as a key strategic orientation of transforming economic development. The province clings to the overall requirements of constructing national circular economy development pilot zones, insists on the center of improving quality and benefit of economic development and takes circular economy as a major approach for breaking down industrial structural contradictions in an effort to greatly promote concentrated development of industries and effectively establish an industrial development situation of circular economy characterized by large regional recycle, intermediate industrial recycle and small enterprise recycle. As a late-developing area in China, the mass and quality of socioeconomic development of Qinghai Province is far lower than that of the eastern provinces or municipalities, for it is restricted by insufficient resources such as financing, human talents and S&T. In the meanwhile, owing to relatively complex characteristics of geographic location, the province is disadvantaged by weak capacity of main market players, poor enterprise independent innovation ability, low industrial level, excessive production capacity of traditional industries, being at formative stage of emerging industries and a lack of big enterprises and big projects that play a supportive and driving role. Over the past few years, its development pace of circular economy is relatively slow. It can be seen from the Scree Plot (Graph 5-4) of hierarchical cluster that Qinghai Province belongs to the third cluster and compared to other provinces and municipalities, its development level regarding circular economy is obviously lagged behind.

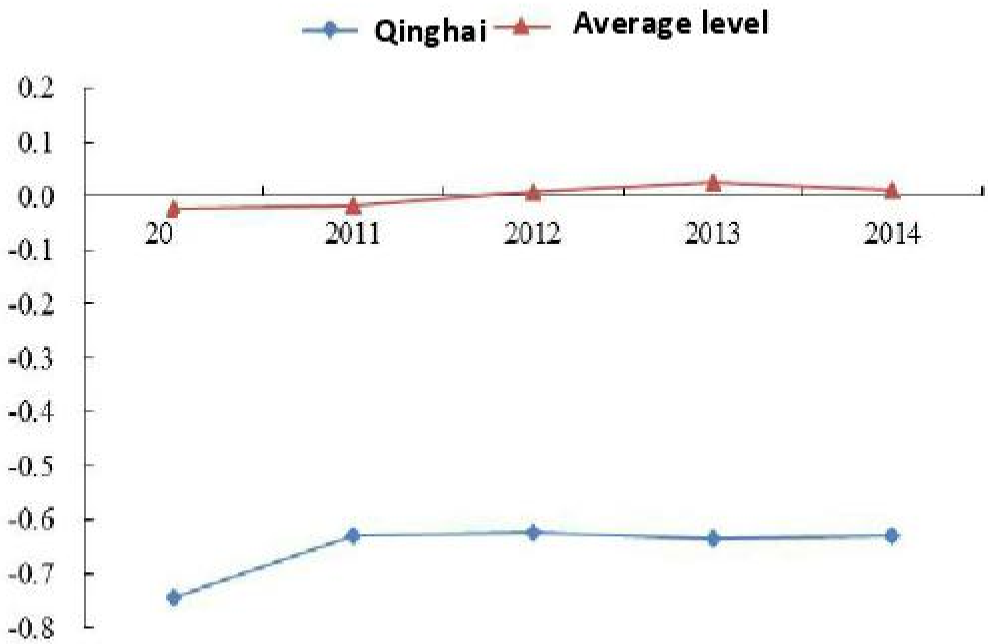


Graph 5-6 Horizontal Comparison of Development Level of Circular economy in Qinghai

2) Vertical Comparison

According to the vertical time series dynamic changes (Graph 5-7), the development level of circular economy in Qinghai has a stable fluctuation in terms of integrated score, with a big growth range in the period of 2010-2011, reaching 0.114 and with the optimum value of integrated scores in 2012 and a slight decline after 2012. Overall, the province's circular economy development has shown a sustainably good momentum. It has to be clearly recognized that there is an obvious gap between its level and the average level of the provinces or municipalities. Over the period from 2010 to 2014, with respect to the development level of circular economy, the province's increase range of integrated scores ranked the second, showing that it has the great development momentum and potential of circular economy. Of course, it is inseparable from the great importance attached to the development of circular economy, the objectives of constructing national recycle development pilot zones and the guideline of establishing a resource-saving and environment-friendly society.

In recent years, the Qinghai Provincial Government has intensified the efforts of consumption reduction for energy saving as well as emission reduction for energy saving, transformed the extensive economy growth mode by ruling out surplus production capacity so that the energy consumption of GDP per unit is annually decreased, the resource use rate obviously improved, the emission of major pollutants clearly controlled, thus producing remarkable effects in terms of consumption and emission reductions for energy saving. Over the period from 2010 to 2014, the integrated energy consumption of GDP per unit decreased from the standard coal of 1.91 tons / per 10,000 yuan to the standard coal of 1.73 tons / per 10,000 yuan; the COD emission of GDP per unit from dropped from 6.15 kilograms / per 10,000 yuan to 4.56 kilograms per 10,000 yuan; the ammonia nitrogen emission of GDP per unit went down from 0.61 kilograms / per 10,000 yuan to 0.43 kilograms / per 10,000 yuan; the sulfur dioxide emission of GDP per unit fell from 10.59 kilograms to 6.70 kilograms / per 10,000 yuan; and the nitric oxide emission of GDP per unit dropped from 9.19 kilograms / per 10,000 yuan to 5.84 kilograms / per 10,000 yuan. In the meanwhile, the Provincial government has paid more attention to recycling and reuse of wastes than before. Over the period from 2010 to2014, the repetitive use rate of urban industrial water increased from 44.62% to 48.2% and the integrated use rate of industrial solid wastes went up from 42.2% to 56.3%. In addition, the Qinghai Provincial Government has made great efforts to adequately implement the pilot work of circular economy of key enterprises in the major parks, so that the pilot work is fully carried out, agriculture, heavy industry and service sectors developed simultaneously in terms of circular economy, and the construction of circular economy policy codes actively promoted, thus providing more refined policy support and legal security for the development of circular economy in Qinghai Province.



Graph 5-7 Vertical Comparison of Development Level of Circular economy

In the period of the "Twelfth Five-Year Plan", the industrial structure has been constantly optimized, the position of 10 key featured industries increasingly highlighted, the industrial chain of circular economy initially formed and emerging and distinctive industries of renewable energy, advanced materials and biological products rapidly developed. Since the period of the "Thirteenth Five-Year Plan" is a transitional and hard-nut critical period of circular economy for Qinghai Province, it is important to get well-informed of the latest S&T and industrial change trends, using innovation as a driving force, to accelerate promotion of structural adjustment, to push industrial transformation and upgrading and to enhance the overall quality and benefits.

In accordance with the *Action Plan of the Construction of National Circular economy Development Pilot Zones in Qinghai*, by 2020, the industrial layout is scientifically rational, the integrated use and output rates of resource remarkable increased, the scale of circular economy constantly extended as the leading development mode, thus gradually creating and completing industrial, agricultural and service-related systems and a society based on circular economy, and establishing an increasing number of national circular economy development pilot zones.

Chapter VI Major Issues Existing in the Circular Economy Development in Qinghai

Empirical results show that in recent years, Qinghai Province has obtained remarkable effects in the practice of circular economy. During the period from 2010 to 2014, the provincial development level of circular economy showed much improvement, with its growth range of integrated scores ranking the second in the thirteenth provinces or municipalities. However, it must be recognized that the development of circular economy in Qinghai Province is relatively lagged behind, (in particular, there exists a big gap compared with the eastern areas) and the situation is not effectively improved. In terms of circular economy development, the province is still confronted with numerous issues. Additionally, according to research realities of parks and enterprise, we have identified a number of critical development issues of parks and enterprises restricting actual operations of circular economy. Therefore, the paper is a discussion of those existing issues regarding circular economy development of the province at the social, park and enterprise levels.

I. Social Level

1. Irrational Industrial Structure & Excessive Resource-Environment Pressure

In 2014, the provincial GDP proportion of the tertiary industry added value was 37%. Actually, the proportion is relatively low, while the primary and secondary industries are proportionally high. The proportion of heavy chemical engineering industries is slightly high with high energy consumption, high input and high pollution since their heavy industrial structure was based on enormous consumption of ecological, environmental and capital resources, thus resulting in the overbearing pressure of resource environment. In addition, there are prominent irrational phenomena of industrial layout as well as obvious industrial structure assimilations, thus causing severe resource constraint and surplus production capacity, having impact over effective distribution of essential production resources and restricting the development of circular economy.

2. Poor Counterpart Infrastructure, Limiting Circular Economy Development

At the initial stage of circular economy, counterpart infrastructure has not kept up with development pace of circular economy in Qinghai. Firstly, there has been lack of well-established systems of renewable resource recovery and trading, sizable renewable resource wastes markets and regional wastes treatment centers, priority regional renewable resource distribution markets and trans-regional renewable resource recovery network. Secondly, there has also been lack of sizable sewage treatment plants and garbage treatment centers, with limited garbage treatment technologies, low capacity of treatment and inadequate setup of urban living sewage plants and counterpart sewage pipe network.

3. Backward Economic Development, Affecting Circular Economy Enhancement

In 2014, the per capita regional GDP in Qinghai was RMB 39,671 yuan, ranking the lowest ones in the thirteen provinces or municipalities. In terms of economic development level, as a backward late-developing province in the western regions, it has a clear development gap compared with the early-developed central and eastern regions. The early-developed areas take advantage of their superior geological locations, resources, financing and human talents, thus having a rapid circular economy development. However, due to the factors of unfavorable economic development level and unimproved industrial structure, plus natural resource endowment and ecological environmental basis, Qinghai Province has an inadequate agglomeration effect in the aspects of financing, technology and human talents and a dearth of key technologies and human talents regarding circular economy, thus to great extent having an impact over the enhancement of circular economy development level.

II. Park Level

1. Lack of Unified Planning & Deployment for Park Public Infrastructure

The development of circular economy in the parks cannot go without well-established construction of public infrastructure and unified planning and deployment. In the process of parks research, it is not uncommon to find that most parks in Qinghai is in financial constraint and that their environment protection infrastructure, especially system of industrial sewage and industrial fixed wastes disposal are relatively lagged behind. In the parks, advance or synergic construction of environmental protection infrastructures is inadequate for pollutants emission, recycling use and improvement in environmental quality, thus increasing constructional and operational costs concerning environment protection of enterprises to be established in the parks, and having impacts over excellent operation of agglomerative and intensive effects with respect to parks construction.

2. Further Extension of Park Industrial Chains

In the course of parks research, it is found that park development planning is not scientific and careful; meanwhile, there is big gap between park program and actual operation. Moreover, the administrative authorities have not carried out effective screening of enterprises to be established in the parks and not take into full consideration the industrial correlation of park enterprises so that there are no much improved mechanism of resource and information sharing and exchange. Such drawbacks have contributed to short industrial chains, fragmental layout, discrepancy in quality and quantity of wastes with respect to park enterprises, thus having not effectively promoted the “recycle” of the whole economic structure. In addition, the park enterprises have not formed closely linked and shared and coexistent ecological heavy industries, with weak intensive level and coordination capacity, thus directly affecting resource use rate and recycling treatment level of wastes.

3. Outdated Park Management and Development

As a governmental branch, the park administration committee should have been responsible for integrated leadership and management of its jurisdiction district.

Unfortunately, most of the surveyed parks informed that, in practice, institutions under the park administration committee do not have the authoritative power of review and approval as well as the authoritative power to allocate governmental funds, thus making park enterprises vulnerable to numerous issues. The administrative and organizational weakness has caused a number of issues concerning industrial park operation. Additionally, there has been a lack of effective system of information support in the parks. At present, most parks have not established their own platforms of integrated information or timely provide services such as information disclosure, information retrieval and scheme and solutions. Without a platform on information service of circular economy that feature governmental leading, enterprise sponsor and industrial promotion and multilateral participation, there will be no way to get all links of circular economy industrial chains in the parks to realize effective connection or to establish close linkages between the parks and the markets of products, capital and human talents.

4. Inadequate Park Service Support System

Inadequate system of park service support system is a common issue in the surveyed parks. Firstly, at present, most parks have not established usual, targeted, institutional relationships with universities or academic or research institutes while they feel it very difficult to seek research projects and to realize industrialization and commercialization of research findings or outcomes vice versa. Secondly, without intermediary service organizations, to realize the sustainable development of enterprises will call for a succession of constant innovations in technology, management, system and organization, and for a wide variety of innovation to be interactive and network-based, there is need for intermediary service organizations to act as a bridge between the enterprises and the markets. Lastly, there are other factors such as backward markets of production elements and commodities as well as undeveloped markets with regard to human talents, financing and technologies in the parks, hindering logical and orderly flow of all elements.

III. Enterprise Level

1. Misunderstandings regarding Circular Economy

According to survey findings on the enterprises, currently, many of them have failed to have a systematical understanding of the connotations of circular economy and the importance and urgency of circular economy development at the moment; and they have only elaborated on circular economy from the perspective of material recovery and use, ignoring its important implications of source prevention and overall process control in terms of material consumption and pollution emission. Furthermore, affected by vested interest, an enterprise largely tends to pursue the maximum economic benefits. Without external constraint, that is, when ecological benefit is only a kind of external benefit for the enterprise, it generally inclined to adopt the extensive development mode of enormous consumption of natural resources and labors, ignoring the recycle development mode of reduced energy consumption. For many enterprises, clean production is merely a new concept so that it is easily confused with the end-treatment in the past, wrongly holding that ecological environmental benefits brought about by clean production are obtained the society, but an enterprise cannot have economic benefit. Plus, as a result of loose legal enforcement of environment management, the enterprises are not highly motivated in developing circular economy.

2. Lack of Effective Organization and Management

There are no clear rights and obligations for safeguarding environmental quality in enterprise departments. Firstly, in the market economy, the primary goal of enterprises is to pursue the maximum of profits, so that there is a lack of holistic consideration. Although corresponding environment protection departments are set up within many enterprises, they cannot play a central role, and as a result of complex procedures and extensive coverage, they have difficulty in coordination, thus lacking good efficiency and performance in environmental maintenance quality. Secondly, due to limited funds, the environmental department in an enterprise is reluctantly established as an expedient strategy, thus finding it difficult to play an important role and to achieve scale effect of circular economy development. As a result of lack of a sense of social and environmental responsibility, no full consideration is given to the environmental impacts in the design, manufacturing, package, transportation of products, wastes disposal, and even pricing and after-sale service relating to products.

3. Lack of Nonprofit Environment Protection Organizations

Nonprofit environment protection organizations have been playing an important role in foreign countries. As NGOs in the field of environment, they carry out monitoring through the implementation process of environmental laws, helping local governments to run the idea of sustainable development through programs regarding economy and social development and supervising enterprises in protecting the environment actively and consciously. According to the survey on enterprises, there has been no adequate attention to the great importance of such organizations in promoting the development of circular economy. Meanwhile, there are no many specialized environmental protection organizations in Qinghai, thus resulting in a dearth of intermediate links. Additionally, most environmental protection organizations are short of funds and human talents, restricting the development of circular economy.

4. Lack of A Sense of Social and Environmental Responsibility

The notion of green consumption is an ideological foundation of circular economy development. Green consumption is an important approach to materializing circular economy development by “Source Reduction”, and it can create good interaction between consumption and production. Therefore, to establish a mode of green consumption is an inevitable approach to the development of circular economy. As a carrier of green consumption, enterprises have played a vital role in the green consumption. Currently, as a result of lack of a sense of social and environmental responsibility, some of them have not give serious consideration to the environmental impacts in the design, manufacturing, package, transportation of products, wastes disposal, and even pricing and after-sale service relating to products, thus triggering a number of issues such as extravagant consumption and large consumption of natural resources.

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研究成果（二）

青海省循环经济发展水平综合评价

《提升青海省循环经济政策建议》

项目办公室

2017 年 2 月

摘 要

课题在充分借鉴国内外循环经济评价的有关经验，同时依据循环经济发展的内涵、目标和原则，充分考虑影响循环经济发展的各种因素，在分析系统结构、层次结构的基础上，结合循环经济评价指标体系的设计原则等从经济系统、社会系统、资源环境系统三方面构建循环经济评价指标体系。并在综合比较各类评价方法的基础上，应用改进的主成分分析法——全局主成分分析法，对 2010-2014 年青海等 13 个省市的循环经济发展水平进行了横向和纵向比较。横向比较可以客观准确了解当前青海省循环经济在我国的发展状况；纵向比较不仅可以了解青海省循环经济发展的变化趋势，而且可以比较不同省市循环经济发展的变化趋势，从发展趋势角度了解当前青海省循环经济在我国的发展状况。主要研究内容：

1. 评价指标构建。从经济系统、社会系统、资源环境系统三方面构建循环经济发展水平综合评价的四层指标体系结构，目标层—系统层—准则层—指标层。整个指标体系由 32 个指标组成，并对指标释义。

2. 评价方法确定及模型构建。国内学者对区域循环经济发展评估研究主要采用熵值、数据包络线、模糊综合和主成分等分析法。基于以上方法优劣势和循环经济发展特点，为避免已有评价方法的缺陷，提高评价模型的科学性与便利性，以获得科学准确的评价结果，本课题采用全局主成分分析法对青海省循环经济发展水平进行综合评价。在此基础上，构建出具体评价模型。

3. 实证分析。课题从横向比较和纵向比较两个角度对青海省循环经济发展水平进行客观准确地评价。横向比较：2015 年，天津、辽宁、上海、江苏、安徽、山东、湖南、广东、重庆、四川、陕西、甘肃、青海等 13 个省市通过了国家循环经济试点单位检查评估和验收。因此，通过这 13 个省市的循环经济发展水平的横向比较可以客观准确了解当前青海省循环经济在我国的发展状况。纵向比较：通过 2010-2014 年上述 13 个省市循环经济发展的纵向时序动态变化比较，不仅可以了解青海省循环经济发展的变化趋势，而且可以比较不同省市循环经济发展的变化趋势，从发展趋势角度了解当前青海省循环经济在我国的发展状况。

4. 结论。横向比较，青海省循环经济发展水平与全国重点地区还存在一定的差距。这种差距需主要是由于技术水平、经济水平、社会建设能力等因素造成。

纵向比较：青海省循环经济发展呈现增长速度快、节能减排成效显著等特点，总体处于向好发展态势。因此，我们必须清楚地认识到，青海省建设国家循环经济先行区任重道远，要深入贯彻习近平总书记系列重要讲话精神，以创新、协调、绿色、开放、共享五大发展理念为引领，牢固树立节约集约循环利用的新资源观，以提高全社会资源产出率为核心，以科技创新、模式创新和业态创新形成引领循环经济发展新动能，通过体制创新和制度供给激发循环经济发展新动力，加快推动全省经济社会绿色循环转型，夯实全面建成小康社会的资源环境支撑，为 2020 年建成全国循环经济的先行者、排头兵打下坚实基础。

目 录

引 言

“十二五”以来，青海省委、省政府立足省情发挥特色优势，发展循环经济成为转变经济发展方式的主攻方向，紧紧围绕建设国家循环经济发展先行区的总体要求，坚持以提高经济发展质量和效益为中心，将循环经济作为破解产业结构性矛盾的主要途径。“十二五”期间，青海省的产业结构不断优化，十大特色优势产业地位更加凸显，循环经济产业链初步形成，新能源、新材料、生物制品等新兴产业和特色产业发展迅猛。“十三五”时期是青海省循环经济承前启后、攻坚克难的关键时期，按照《青海省建设国家循环经济发展先行区行动方案》，到 2020 年，产业布局科学合理，资源综合利用和产出率显著提高，循环经济规模不断扩大，成为发展主导模式，最终建成国家循环经济发展先行区。

为了探索更有效的循环经济发展途径，实现循环经济发展的新突破，完成“十三五”时期建成国家循环经济发展先行区的目标，有必要对循环经济发展的现状进行全面剖析，从而为循环经济的进一步发展指明方向。因此，当前对青海省循环经济发展水平进行综合评价是尤为必要的，一是可以准确了解当前青海省循环经济的发展水平以及未来的发展趋势，二是可以为政府规划政策和保障措施的制定提供理论和现实依据。

第一章 循环经济发展的内涵及影响因素分析

一、循环经济发展的内涵

（一）循环经济发展的概念

从全球范围看，随着世界人口数量的不断增加，维系经济社会发展的资源能源已经难以为继，生态环境更是不堪重负，人类发展面临巨大挑战。这表明，传统经济运行模式在推动和实现可持续发展方面的问题越来越多，甚至到了无能为力的地步，人类发展需要以新的经济增长方式作支撑。因此，自 20 世纪 70 年代起，世界各国对传统掠夺式利用资源和线性增长模式、自身生产生活行为进行深刻反思，开始探寻如何转变经济发展模式，实现新的发展。同时，各国政府以及国际组织也将这一问题纳入议事日程。

循环经济思想萌芽于 20 世纪 60 年代。1966 年，美国经济学家波尔丁在宇宙飞船理论的基础上，提出了循环经济概念[1]。循环经济的提出引起了全球广泛的关注和各界的共识。它是一种从传统发展观的破产到以人与自然关系的和谐、全体社会同自然界协调和睦、共生共荣为内容的新的经济发展模式，代表了对传

统经济运行系统的创新方向。1972 年，一个由多国科学家、经济学家和企业家组成的跨国民间学术组织团体——罗马俱乐部，发表了研究报告《增长的极限》，其中第三章为《人均资源利用》，专门说明资源循环问题，指出自然资源，尤其是稀缺自然资源，将制约发展直至最终将使其停止而达到增长的极限。这份报告首次正式向世界发出了警告："如果在世界人口、工业化、污染、粮食生产和资源消耗方面按现在的趋势继续下去，这个行星上的增长极限有朝一日将在今后一百年中发生"。这份报告被认为是第一次系统地考察了经济增长与人口、自然资源、生态环境和科学技术进步间的关系问题。1983 年， 联合国世界环境与发展委员会开始研究"没有极限"的可持续发展问题，并于 1987 年提出了《我们共同的未来》研究报告。报告专门用《公共资源管理》一章探讨如何通过管理实现资源的高效利用、再生和循环，提出了按生态系统的自然规律、循环利用自然资源，解决可持续发展的问题。至此，循环经济的概念正式出现，并为国际社会所关注。

循环经济的提出，也启发了 20 世纪 60 年代末开始的关于资源和环境的国际经济研究。研究认为，循环经济实质是以尽可能少的资源消耗和尽可能小的环境代价实现最大的发展效益，其意义首先是一种新的发展理念，其次是一种新的经济增长方式，再次是一种新的污染治理模式。

《中华人民共和国循环经济促进法》将循环经济定义为"循环经济是指在生产、流通和消费等过程中进行的减量化、再利用、资源化活动的总称"。国家发展和改革委员会环境和资源综合利用司提出的定义为"循环经济指通过资源的循环利用和节约，实现以最小的资源消耗、最小的污染获取最大的发展效益的经济增长模式；其原则是减量化、再利用、资源化；其核心是资源的循环利用和节约，最大限度地提高资源的利用效率；其结果是节约资源，提高效益，减少环境污染"。因此，可以看出循环经济是兼顾发展经济、节约资源和保护环境的一体化战略。

（二）循环经济发展的内涵

对循环经济的内涵，目前学术界尚无一致看法，各学科专家学者、应用研究人员、各界人士均从各自专业领域、从不同角度理解和研究循环经济问题，对循环经济给予界定[2]。代表性的观点主要有：

1、广义的循环经济

循环经济涵盖经济发展、社会进步、生态环境三个方面，追求这三个系统之间达到理想的组合状态。广义的循环经济是指围绕资源高效利用和环境友好所

进行的社会生产和再生产活动，目的是以尽可能少的资源环境代价获得最大的经济效益和社会效益，实现人与自然和谐发展。因此，广义的循环经济，不仅关注工业系统、社会系统内部循环经济体系建设与发展，更重要的是把人口、资源、环境、经济、社会等因素纳入循环经济理论体系。也就是说，广义的循环经济是在人、自然资源和科学技术的大系统内，在资源投入、企业生产、产品消费及其废弃的全过程中不断提高资源利用效率，把传统的、依靠资源消耗增加发展转变为依靠生态型资源循环发展的经济，实现人与自然和谐发展，资源效率和环境友好有机的统一，将资源效率和环境友好作为循环经济的核心。

2、狭义的循环经济

狭义的循环经济，主要是指废物减量化和资源化，通过废物的再利用、再循环等社会生产和再生产活动发展经济，相当于“垃圾经济”、“废物经济”。一般说来，经济都是相对于一定的社会生产活动，而且总与一定的产业相对应。例如，循环经济概念产生的德国和日本，与之对应的是“静脉产业”。所谓“静脉产业”是指废弃物资源化形成的产业，它是相对于“动脉产业”而言的。“动脉产业”是指开发利用自然资源形成的产业。根据我国的基本国情，我国要倡导和推进的循环经济，不应局限于狭义的范畴。

3、生态学、环境保护角度的循环经济

循环经济思想源于生态平衡和环境保护，因此较多的循环经济定义偏重于生态学和环境保护的内涵。研究者认为，循环经济本质上是一种生态经济，是一个具有时代性的环境保护发展模式，表现为经济发展过程中物质和能量循环利用的一种新型经济发展方式，使污染物做到“低排放”甚至“零排放”，并把清洁生产、资源综合利用、生态设计和可持续消费等融为一体，实现经济发展过程中物质和能量循环利用，将经济系统和谐地纳入到自然生态系统，实现经济活动的生态化。

4、经济学角度的循环经济

循环经济的提出是人类对传统经济发展模式深刻反思的结果，它作为一个新的经济活动过程和增长方式，是一种新的经济形态，而不是一个单纯的经济要素。循环经济是应对资源节约和环境约束，以“低消耗、低排放、高效率”资源循环利用为主要特征，以环境友好的方式利用资源，使所有的原料和能源都在不断循环的经济过程中得到合理和高效利用，倡导人类生产活动纳入生态、经济、社会和谐共生的自然循环过程之中，将保护环境和发展经济有机地结合起来，使经

济活动对自然环境的影响尽可能控制在较小的程度之内。还有人提出：循环经济与市场经济存在同一性，二者都符合经济发展规律。

5、技术经济学角度的循环经济

有学者从技术经济学角度把循环经济看作是一种范式革命，在此基础上，反映其经济形态的本质。如冯之浚教授在《循环经济是一个大战略》一文中指出，循环经济是一次范式革命。主要体现在四个方面：第一，生态伦理观由"人类中心主义"转向"生命中心伦理"和"生态中心伦理"。末端治理的生态伦理是以人类为中心的，而循环经济强调的伦理，主张在生产和消费领域向生态化转化，承认"生态位"的存在和尊重自然权利。第二，生态阈值问题受到广泛关注。循环经济强调在阈值的范围内合理利用自然资本，是一种在尊重自然权利的基础上切实有力地保护生态系统的自组织能力。第三，自然资本的作用被重新认识。循环经济将自然资本列为最重要的资本形态，是人类社会最大的资本储备，提高资源生产率是人类社会最大的资本储备，是解决环境问题的关键。第四，认为循环经济上从浅生态论向深生态论的一种转变。

6、生产模式角度的循环经济

循环经济改变了传统经济"资源——产品——废物"单向流动的线性经济，实现了"资源——产品——再生资源"的自然和谐式循环生产模式。如邹声文认为，循环经济追求资源利用最大化和污染排放最小化，是一种将清洁生产、资源综合利用、生态设计和可持续消费等融为一体的经济发展战略。江金骐认为，循环经济是指依靠人的智力和智力产生的科技进步，按照清洁即无公害的生产方式，将资源和废弃物作为一种循环使用的原材料，重复多次使用，在产品生产过程中不发生或少发生污染。

二、循环经济发展的作用

（一）循环经济发展的目标

依据循环经济基本理论，人类发展循环经济的最高宗旨是在生态可持续条件下实现人类社会经济发展不断进步，这也是循环经济发展的总目标。此总目标又可以分解为三个子目标:减物质化；实现代际间环境资源公平利用；满足人类整体发展及福利增长[3]。

1、减物质化

发展循环经济的基本目标之一是实现资源环境强约束下的经济社会发展，

通过大幅度提高生态效率实现减物质化。循环经济是仿生态的经济模式，在闭路循环的生产系统中,按照以自然为核心的设计理念，每一种产品最终要么作为一种像混合废料那样的养料，无害地回到生态系统中去；要么变成一种用于另一种产品生产的原材料。“大自然中一物种的消耗成为另一物种的食物，混乱和失衡虽然也会发生，但生态圈一般能实现自我纠正和自我恢复，一个循环和恢复型的经济也应该在从摇篮到摇篮的生命循环中运转，而不是在从摇篮到坟墓的过程中运转，每个产品或副产品在被生产出来前就已想好了它随后的形态，设计者必须从一开始就把这一产品将来的用途及如何避免废物考虑在内，这样，就不会产生危险的和生物学上无用的废物”。我们对于企业生产模式的要求必须从以劳动生产率为中心转向以资源生产率（提高资源利用率）为中心，即循环经济所倡导的减量化。

2、实现代际间环境资源的公平利用

循环经济发展的另一基本目标就是实现生态可持续发展。按照 1987 年《我们共同的未来》中对于“可持续发展”定义的首次生动阐述，代际公平为可持续发展的关键含义，循环经济发展特别关注环境资源利用的代际公平。目前经济系统的增长受到了资源环境的强约束，对于自然资源的非减性和非缺性造成了威胁。社会分工越来越明确，科学技术越来越发达，粗放式的生产方式和生活方式，不断刷新人与自然之间物质变换的规模和程度记录，若改变不再发生，影响到代际间对于自然环境资源的公平享用，此区域将表现为不可持续的增长。

3、满足人类整体发展及福利增长

在以实现人类可持续发展为目标的循环经济视域下，人类整体福利的持续性提高是其高端追求。随着循环经济的进一步发展，在减物质化模式下，技术的发展路径由末端处理转向对生态效率提高的追求；“聪明的产品体系”使得“服务经济”成为企业流行语，人类社会由目前的物质社会进入功能社会；商业活动实现生态化，健康商业大大提高自然生产率，以减少对自然资源的使用，从大量消耗资源的社会进入到无(少)资源消耗的社会。

（二）循环经济发展的原则

自我国引入循环经济相关理论以来，学术界对制定适合我国国情的循环经济发展的原则的探讨就从未停止过。在初期的理论探讨、理论倡导阶段，学术界普遍以“减量化、再利用、再循环（资源化）”作为我国循环经济发展的主要原则，

简称“3R”原则。随着我国循环经济的试点与推广，研究者对循环经济有了更深的认识，通过理论与实践的不断探索，学者们又补充了“再思考”“再修复”“再组织”“再制造”“无害化”等原则。这些原则对传统的“3R”原则进行了有益的补充，对我国循环经济的发展起到了积极的作用。

1、减量化原则

减量化原则要求从物质流的输入端开始控制，旨在用较少的资源能源投入来达到预定的生产目的和消费目的，在经济活动的源头就注重节约资源和减少污染。在生产过程中，在不影响产品质量、安全的前提下，利用生态设计和先进的管理方式，尽可能降低输入产品生产系统中的物质和能量，减少排入自然生态系统的污染物。在消费过程中，倡导节约、适度消费的理念，鼓励人们由过度消费向适度消费和“绿色消费”转变；提倡人们购买耐用的可循环使用的物品而不是一次性物品以减少垃圾的产生。

2、再利用原则

再利用原则要求从物质流过程的各个环节进行控制，在物质的生命周期范围内尽可能地多次重复使用产品或包装物品，目的是通过延长产品的服务寿命来减少资源的使用量和污染物的排放量。在生产过程中，使用标准尺寸进行设计实现部分优化替代的技术，以防止因产品某元件的损坏而导致整个产品的报废；使用生产质量好、技术高的设施设备以延长固定资产的使用年限。在消费过程中，要求人们对消费品进行修理而不是频繁更换，提倡二手货市场化；将可维修的物品返回市场体系供别人使用或捐献自己不在需要的物品；或重复使用包装袋等，避免其过早成为垃圾。

3、再循环（资源化）原则

再循环原则要求对物质流的输出端进行控制，是指废弃物的资源化，使废弃物转化为再生原材料，重新生产出原产品或次级产品。一方面对生产系统内部产生的废弃物进行综合利用，使之最大限度地成为另一生产系统所需的原材料；另一方面对消费后形成的废旧物品进行资源化处理，使之成为再生资源，形成再生产品。与资源化过程相适应，应该鼓励消费者和生产者购买使用再生资源制成的产品，使得循环经济的整个过程实现闭合。

“3R”原则在循环经济中的重要性并不是并列的，其优先顺序是：减量化—再利用—再循环（资源化）。其要义是，首先要减少经济源头的污染物的产生量，

因此在生产、流通、消费阶段就要尽量避免各种废物的排放；其次是对于源头不能消减又可利用的废弃物和经过消费者使用的包装废物、旧货等要回收利用，使它们回到经济循环中去；只有那些不能利用的废弃物，才允许做最终的无害化处置。例如 1996 年生效的德国《循环经济与废弃物管理法》，规定了对待废弃物的优先顺序为避免产生—循环利用—最终处置。

"3R"原则的优先顺序，实际上反映了 20 世纪下半叶以来人们在环境与发展问题上思想进步走过的三个历程：首先，以环境破坏为代价追求经济增长的理念终于被抛弃，人们的思想从排放废物进化到净化废物（通过末端治理方式）；随后，进一步从净化废物升华到利用废物（通过再利用和再循环）；最后，人们认识到利用废物仍然只是一种辅助性手段，环境与发展协调的最高目标是实现从利用废物到减少废物的质的飞跃。

（三）循环经济发展的作用

第一，循环经济发展可以充分提高资源和能源的利用效率，最大限度地减少废物排放，保护生态环境。传统工业经济是由"资源—产品—废物和污染排放"所构成的单向物质流动的经济。在这种经济中，人们以越来越高的强度把自然资源和能源开采出来，在生产加工和消费过程中又把污染和废物大量地排放到环境中去，对资源的利用常常是粗放的、一次性的。循环经济倡导建立在物质循环利用基础上的经济模式，根据资源输入减量化、延长产品和服务使用寿命、使废物再生资源化等原则，把经济活动组织成一个"资源—产品—再生资源—再生产品"的循环流动过程，使得整个经济系统从生产到消费的全过程基本上不产生或者少产生废弃物，最大限度地减少废物末端治理。

第二，循环经济发展可以实现社会、经济和环境的共赢。传统的线性经济和末端治理相结合的资源利用方式，忽视了经济结构内部各产业之间的有机联系和共生关系，忽视了社会经济系统与自然生态系统间的物质、能量和信息的传递、迁移、循环等发展模式，导致许多自然资源短缺与枯竭，产生严重的环境污染，造成对经济社会、人体健康的重大损害。循环经济以协调人与自然关系为准则，模拟自然生态系统运行方式和规律，实现资源的可持续利用，使社会生产从数量型的物质增长转变为质量型的服务增长。同时，循环经济还拉长了生产链，推动环保产业和其他新型产业的发展，增加就业机会，促进社会发展。

第三，循环经济发展在不同层面上将生产和消费纳入可持续发展的框架。

传统工业经济的发展模式将物质生产和消费割裂开来，形成大量生产、大量消费和大量废弃的恶性循环。目前，发达国家的循环经济实践已在三个层面上将生产和消费这两个最重要的环节有机地联系起来：一是企业内部的清洁生产和资源循环利用；二是共生企业间或产业间的生态工业网络；三是区域和整个社会的废物回收和再利用体系。循环经济把清洁生产、资源综合利用、生态设计和可持续消费融为一体，运用生态学规律来指导人类社会的经济活动，其根本目的就是要保护日益稀缺的环境资源，提高环境资源的配置效率。

三、循环经济发展影响因素分析

除运用案例分析总结影响因素外，学者们从各自视角对循环经济发展影响因素进行了论述。于蕾（2009）将我国当前推进循环经济发展的阻碍性因素总结为五个方面：制度障碍、法律障碍、思想障碍、社会机制障碍及科学技术障碍。Su 等（2013）对中国循环经济从基本概念形成到发展实施的过程进行了评述，比较了北京、天津、上海和大连四个“试点”城市的循环经济发展现状，总结出共同的制约因素：缺乏有效的信息平台、缺乏标准的评价体系、公共意识薄弱等。由于企业是循环经济微观层面的实践单位，循环经济在企业的实施状况在某种程度上决定了所在园区甚至是区域的循环经济发展水平。Shi 等（2008）对中小企业开展清洁生产的障碍因素分为四类：政策和市场障碍、金融和经济方面的障碍、技术和信息上的障碍，管理和组织上的障碍。

吴宝华（2011）较为系统地归纳总结了循环经济发展的影响因素，分为三类：直接因素、间接因素以及机制性因素[4]，涵盖了循环经济发展过程中的各类因素（见图 1-1）。

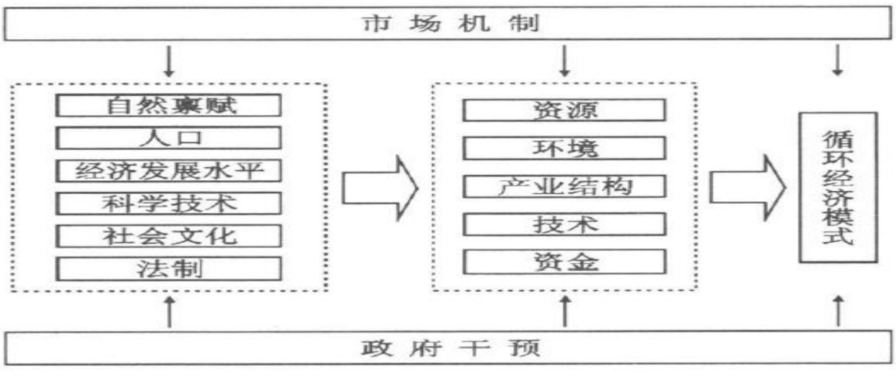

图 1-1　循环经济发展的影响因素

（一）直接因素

1、资源。循环经济的实践和理论是建立在人们对资源稀缺性的认识基础之上的。资源的存量、可利用量，资源的类型和不同资源类型的组合，产业发展对资源的依赖程度，资源的利用方式和利用效率等因素，都直接影响着循环经济模式的选择。

2、环境。人类的生产活动和生活活动必须考虑环境的承载力。环境污染和环境压力过大是目前大部分国家普遍面临的问题。在我国，不同区域面临的环境问题类型和程度是存在差异的，这就要求在选择循环经济模式时，要在准确把握各个区域面临的环境问题的基础上， 把发展循环经济与环境治理结合起来。

3、产业结构。产业结构和布局是关系到循环经济发展成功与否的关键因素之一。只有在考虑产业结构和布局的同时，兼顾资源的可持续供给、环境的生态安全以及经济的绿色增长，循环经济的发展才有成功的基础。一个区域的产业结构是该区域自然禀赋、经济发展水平以及科学技术水平综合作用的结果。产业结构的现状构成了循环经济的实施基础，并影响着循环经济的推进方式。因此，循环经济的推进往往和产业结构的优化结合在一起。

4、技术。循环经济自产生之日起就和技术密切相关。循环经济的核心思想——"减量化、再利用、资源化"，需要相应的技术手段为支撑才可能实现。发展资源回收、再生性资源产业和环保产业，改造高消耗的传统产业，实现传统产业的绿色生态转型，都必须依靠科技进步。技术在提高资源利用效率、替代资源能源的开发、降低资源能源消耗、污染物减排和废弃物转化等方面正在发挥着越来越重要的作用。在选择循环经济模式时，必须考虑本区域技术水平，以及发展循环经济所需技术的成本和可获得性。

5、资金。高投入是循环经济发展的基本特征和重要条件。循环经济技术比传统技术复杂得多，往往涉及多个学科领域，对设备、原材料的要求更高，技术更新速度更快，使得企业设备更新和折旧的速度大大加快，因此，需要的资金量也大大高于传统产业。循环经济技术的创新需要大量的资金支持，而要将科研成果转化为现实生产力，进而发展成为一个个微观循环经济体系，由点带面形成更大范围的中观和宏观循环经济体系，没有强大的资金支持是不可能的。

（二）间接因素

1、自然禀赋。自然禀赋是人类所有生产和生活活动的基础。自然禀赋不仅从根本上影响着所有的直接因素，而且也影响其他间接因素。不同区域的自然禀

赋在类型和总量上的差别，影响着资源、环境的差异，也通过对经济发展水平的影响间接影响着产业结构和技术水平等因素。从循环经济的角度考察，自然禀赋一般包括矿产资源、土地资源、水资源和气候资源等。

2、人口。从某种程度上说，人口因素是自然禀赋的一个变量。人均可利用的资源数量比资源总量更能说明人类所面临的资源和环境状况。我国庞大的人口数量，决定了我国资源短缺、环境压力等普遍性特征。此外，人口也被视为一种资源——人力资源，人力资本理论和现代人力资源开发理论已经揭示了人力资源在经济和技术发展等方面的巨大能动作用和贡献。

3、经济发展水平。一个区域的经济发展水平，与该区域的自然禀赋、人口和人力资源、科学技术以及社会文化之间存在相互影响的关系。而一个区域的资源需求量、环境压力、产业结构、技术水平以及资金供给能力，却更直接、更主要地受当地经济发展水平的影响。

4、科学技术。科学技术的发达程度往往和经济发展水平相关。在经济发展能够提供所需支持的前提下，一个区域的基础性科研水平越高，科研力量越雄厚，这个区域的技术创新和扩散的能力也就越强，适用技术得到广泛应用的可能性也就越高。循环经济从它产生之日起就具备了明显的技术特征，循环经济的发展是以大量的技术创新和技术扩散为支撑的。

5、社会文化。社会文化同样和其他间接因素间存在互相影响的关系。在循环经济的实践中，人们对于循环经济的理解和认同程度构成了发展循环经济的"软"环境。不同区域由于社会文化上存在一些具体的差异，对于循环经济理念的认同程度以及对循环经济的理解也是存在差异的。这种理念和认识上的差异不会直接影响循环经济模式的选择，但会对循环经济的发展形成支撑或制约作用。

6、法制因素。发展循环经济，没有法律制度的保障和推进是不可能实现的。一方面，循环经济是新生事物，人们受习惯影响，接受较慢。法律制度具有公共选择型、强制性、权威性和见效快等特点，可以较快地推进循环经济。另一方面，循环经济需要更高的资金投入、智力投入和更多的自我约束，从而会加大人们的工作负荷。一个区域的法制状态，尤其是关于循环经济的立法完善程度将会影响循环经济发展模式的选择和推进策略的选择。

（三）机制性因素

1、政府干预。在循环经济的初始阶段，政府的推动作用是必须的，也是至

关重要的，循环经济的产生已经证明了这一点。政府作用要以市场有效发挥作用为前提，不能代替市场，而是要培育市场，为市场主体提供公共产品和公共服务，降低其交易成本。在实践中，政府部门是否具备相应的意识与能力履行这些职责，是否会出现“缺位”或“越位”等问题，直接影响着区域循环经济的发展速度和质量，而且建立和完善循环经济的激励约束机制，只能以政府为主导。

2、**市场机制**。循环经济的理论前提是自然资源正在成为制约人类发展的主要因素，它考虑的是如何在既定资源存量下提高资源的利用效率和经济发展的质量问题。因此，运用市场机制发展循环经济比使用强制手段有更高的效率和更少的管理成本，尤其是价格杠杆在发展循环经济中的重要作用不可忽视。

第二章　国内外循环经济评价指标体系及方法概况

一、美国循环经济评价指标体系及方法

（一）美国循环经济发展现状

发展循环经济不仅是美国推进经济进步的重要举措，而且成为普通美国人日常生活的一部分。美国是一个生产大国，更是一个资源消费大国。过去，美国主要以低价购买的方式从世界各地便捷地获取资源，这也使美国废旧物品回收利用率较低。但随着资源环境破坏程度的不断加深及公众环境保护意识的不断提升，改变旧有资源利用观念，探索一条以废旧物品回收处理为主要方式的资源再利用道路成为必然。以循环经济取代传统经济，是美国以资源再利用的方式发展经济的重要转变，经过多年的探索，循环经济理念也逐渐深入到美国人的日常生活中。

美国政府十分重视本国循环经济的发展，建构起以政府为中心、企业为依托、公民为保证的循环经济发展模式，通过制订计划、规划，引导企业参与，同时注重培养公民发展循环经济的意识，进而促进循环经济的快速发展。具体而言，美国政府为推进循环经济发展主要采取了以下措施。

1、制定发展循环经济的规划及法规

美国重视循环经济发展规划的制定，并且在发展规划中使用了明确的指标来保证循环经济发展目标的实现。与此同时，与规划相配套的法律法规也得到了完善。在美国，各州都有自己的法律法规，一些州甚至根据自身的情况制订了促进资源再生循环利用的法律法规。

2、提供有力的技术支持

长期以来，美国鼓励各科研组织研究资源的循环利用：一方面，政府为这些科研组织提供经费支持；另一方面，利用先进技术建设废弃物循环利用的设施。除此之外，美国政府还出台了各种政策鼓励和支持循环技术的研发，包括在政府的协调和统筹下，进行可再生能源和清洁能源技术的研发和创新等。

3、督促企业参与循环经济工作

美国政府制订了严格的环保法规，这些法规明确规定了企业在处理生产过程中产生的废弃物方面应承担的责任以及因担责而享有的优惠政策。这一做法为企业参与循环经济提供了动力。此外，就企业自身而言，节约资源、促进废弃物的再生利用等，不但可以在公众心目中树立起负责任的企业形象，而且能为企业自身塑造品牌，带来品牌效应。

4、鼓励全民参与循环经济

美国公众参与循环经济的意识是在长期的实践中逐步培养起来的。一方面，美国政府通过宣传教育逐步提高人们的节约和环保意识。如确定每年的 11 月 15 日为美国循环日，一些机构如全国再生循环联合会每年都对合理进行资源再生利用的机构和个人给予奖励，同时在全社会进行宣传，鼓励更多机构和个人参与循环经济。另一方面，借助二次交易开展循环经济。eBay 是美国专营旧货拍卖的网站，体现了美国发展循环经济的一大特色，公众可以在网站上自由交易一些二手货，实现了资源的二次分配[5]。

（二）美国循环经济评价指标体系构成

1992 年 6 月联合国在巴西里约热内卢召开的环境与发展大会中号召各个国际组织和非政府组织建立和运用可持续发展的指标体系。自此有关环境与可持续发展的指标体系不断提出，如联合国可持续发展委员会（UNCSD）提出的“驱动力-状态-响应”指标体系；联合国统计局（UNSTAT）发布的可持续发展指标体系框架；国家科学联合会环境问题科学委员会（SCOPE）和联合国环境规划署（UNEP）在《人类发展报告》中提出的一套高度合并的可持续发展指标体系。

美国著名生态学家 H.T.Odum 于 20 世纪 80 年代末提出“能值理论”的指标体系。20 世纪 90 年代奥地利、德国、日本、荷兰、美国共同合作发展了物质流核算体系。1997 年由美国世界资源研究所（WRI）牵头，将这些国家合作的结果发表在《国家的重量》报告上，在这个研究报告中提出了直接物质输入、国内过程输出等用于表征一个国家物质流的指标体系数。1997 年美国生态学家 Brown M.T.和意大利生态学家 Ulgiati S.首次提出了能值可持续指标 ESI。随着环境保护运动的发展和可持续发展理念的兴起，一些经济学家和统计学家们，尝试将环境要素纳入国民经济核算体系，以发展新的国民经济核算体系，这便是绿色 GDP。绿色 GDP 是对 GDP 指标的一种调整，是扣除经济活动中投入的环境成本后的国内生产总值。

生态效率一词最早来源于生态学，指的是生态系统中各营养级生物在能量流动过程中利用能量的效率，以能量流动线上不同点之间的比值来表示[6]。20 世纪 90 年代以来，生态效率概念被引入可持续发展领域。1990 年 Schahegger 和 Sturm 首次提出环境绩效测度指标——生态效率，其符合循环经济使用较少的资源创造出更多的价值的指导思想与目的[7]。

表 2-1 生态效率指标体系

类型	指标
投入	企业生产或经济体消耗的资源和能源及造成的环境负荷
产出	企业生产或经济体提供的产品和服务的价值

（三）美国循环经济评价方法

能值分析法是系统生态学常用的方法，它以能量为衡量单位，从总体上，探讨人类社会与自然环境间的能量流动。能值以太阳能为基本单位，包含了量(即能量）和质（通过能换率而得），并通过能值指标衡量自然资源与人类活动之间的相互关系。根据能量守恒原则，当自然资源被利用时，其转换成其他形式的能量，那么转换前后的能量是相等的。利用能值分析法评价循环经济发展时，将作为输入端的资源和输出端的产品和废弃物都转化为相同的能量单位，可以评判出整个循环经济系统的能量利用率以及能量的循环率。

物质流分析法是对经济活动中的物质流动状况进行分析，通过建立相应的指标体系，来评价经济活动的效率、资源、对环境的压力等。它的基础是物质的投入和产出，通过进行量化分析，建立物质投入和产出账户，以便对循环经济进行评价，并进行以物质流为基础的优化管理。

生命周期分析法是一种对产品、生产工艺及活动对环境的负荷进行评价的客观过程，它通过对能量和物质利用以及由此造成的环境废弃物排放进行辨识和量化，来评估能量和物质利用对环境的影响，以寻求改善的途径。该评价方法通过对产品生产过程中物质和能量的输入输出，弄清产品资源和能源的投入量，弄清环境释放物种类、数量及对环境影响的类型和程度，从而改变原材料、能源组成，改进工艺，改变废弃物管理方式等，以获得更好的环境效益和经济效益。循环经济的经济系统要求在减少资源输入流的同时减少污染输出流，生命周期分析从资源和能源的整个流通过程对物质消耗和污染排放进行分析，从而得到全过程全系统的物流情况和环境影响，以此评价系统的生态经济效益的优劣。

（四）经验借鉴

循环经济已经成为美国经济发展的重要方式之一，美国在发展循环经济过程中积累的经验，能够为我国提供借鉴：第一，政府部门必须在本国循环经济的发展中发挥主导作用，通过制定循环经济专项法规和《循环经济发展规划》来促

进本国循环经济的发展；第二，社会各界的积极参与是循环经济成功发展的重要保证，必须吸引企业、非营利性机构、个人参与到循环经济发展中；第三，利用各种媒介进行循环经济宣传，促进全民参与循环经济工作，这些都是循环经济持续发展的重要基础。

二、德国循环经济评价指标体系及方法

（一）德国循环经济发展现状

20 世纪 80 年代后期，循环经济在德国逐渐发展和兴盛起来，严谨的德国人通过构建系统的支持机制来促进德国循环经济的发展，尤其是建立了比较完善且富有特色的废弃物管理体系。德国是世界上最早开展循环经济立法的国家之一，早在 1972 年就制定和颁布了《废弃物处理法》；1986 年颁布了新的《废弃物管理法》；1994 年颁布了《物质闭合循环与废弃物管理法》，首次提到“循环经济”一词；1996 年又在此基础上颁布了《循环经济和废弃物管理法》，确立产生废弃物最小化原则、肇事者原则以及政府与公民合作原则，明确了企业在发展循环经济中的责任，促进企业把循环经济理念作为自身发展的不可分割的一部分。

德国循环经济发展水平较高主要得益于其对本国循环经济发展中核心问题的把握以及在此基础上构建的支持机制。德国在发展循环经济过程中的主要做法如下。

1、制定循环经济发展的法律法规

为促进循环经济发展，德国出台了一系列法律法规，特别是对废弃物管理予以了极高的重视。1996 年颁布实施的《循环经济和废弃物管理法》，是德国支持循环经济发展的法律体系成熟的标志，它明确规定了采取减量化措施减少废弃物的产生量，并且明确了废弃物生产者、拥有者和废弃物处置者的基本责任和义务，特别强调和规定了政府的表率作用。在《循环经济和废弃物管理法》的框架下，德国根据各个行业的不同情况，制定促进该行业发展循环经济的法规。如《饮料包装押金规定》、《废旧汽车处理规定》、《废木料处理办法》等，对各行业的废旧物处理做了具体规定，使循环经济发展的支持机制愈加完善，成效日益显著。

2、创办垃圾再利用服务公司

与其他国家主要靠政府引导不同，德国还建立了一类非政府组织——能提供垃圾再利用服务的公司。这类公司不仅能够为缺乏垃圾处理技术的企业提供回

收再利用服务，还能为已建立垃圾回收利用系统的企业提供技术咨询，这使得垃圾再利用服务公司的作用得到了凸显。一方面，它弥补了政府在循环经济发展过程中无法兼顾所有企业的不足；另一方面，也满足了有构建自由垃圾处理系统意向的企业的需求。

3、建立发展循环经济的监督机制

监督机制作为经济发展中重要的反馈机制，对循环经济的发展起着重要的作用。德国建立了专门的监督企业废弃物回收和执行循环经济发展规定的机构，同时要求生产者必须向监督机构证明有足够能力回收废旧产品才能从事生产和销售活动，企业产生的垃圾种类、规模和处理措施也要向该部门进行事前报告。年废弃物排放量在2000吨以上的具有较大危害的生产企业还需提交废弃物处理方案[5]。

（二）德国循环经济评价指标体系构成

20世纪90年代初，德国Wuppertal研究所提出了物质流账户体系（Material Flow Accounts，MFA）[8]，在过去几年中各类MFA在改进和规范化方面取得了很大的进展，在欧盟已建立了一个综合性的国家物质流核算标准。2001年欧盟委员会统计局（EUROSTAR）在编制MFA的基础上导出了一系列用于表征一个国家或地区全社会经济范围物质的输入、消费、输出、外贸平衡等描述实物质流的指标体系，制定了“经济性的物质流核算和派生指南”，这个指南为欧盟成员国编制全社会经济范围的物质流的核算和综合平衡提出了总体框架。

表2-2　德国物质流指标体系

类型	指标
投入	直接物资投入（DMI）
	物资总投入（TMI）
	物资总需求（TMR）
消费	国内物资消费（DMC）
	物资总消费（TMC）
	外贸实物量平衡（PTB）
输出	国内过程输出（DPO）
	国内总输出（TDO）
	直接物资总输出（DMO）

	物资总输出（TMO）

1、投入指标

直接物资投入（DMI），DMI 衡量了用于经济活动的直接物资投入，也即从自然界开采的具有经济价值并且用于生产和消费活动的所有物资，DMI=国内开采的原材料+进口物质。

物资总投入（TMI），TMI 包括了直接物资投入以及伴随经济活动从自然界开采的不能用于生产或消费的物资，TMI=DMI+国内隐性物资投入。

物资总需求（TMR），TMR 为物资总投入再加上相应进口物资在进口国伴生的隐性物资，物资总需求表示了支撑全社会总的物质基础，TMR=TMI+进口物资在进口国伴生的隐性物资。

2、消费指标

国内物资消费（DMC），DMC 度量了全社会经济活动直接使用的物资总量，DMC=DMI-出口物资。

物资总消费（TMC），TMC 度量了全社会生产和消费使用的物资总量，也包括了相应进口物资伴生的隐性物资，TMC=TMR-（出口物资+出口物资在该国伴生的隐性物资）。

外贸实物量平衡（PTB），PTB 度量了外贸实物量的盈余或赤字，PTB=进口物资-出口物资。

3、输出指标

国内过程输出（DPO），进入到社会生产和消费的经济活动边界内直接物资投入，其中相当部分的物资变成增加的存量，仍存留在社会的经济活动的边界范围内，包括新建造的建筑物和基础设施的物资，商品库存增加的物资，新购置的机构设备、交通设施以及家电、家具等耐用消费品的物资。其他的物资则在运输、加工、制造、使用以及最终处理的生产和消费活动链中从经济活动边界内排出，进入到自然环境中，这部分的物资总量即为国内过程输出。国内过程输出包括了排放到大气的废弃物，工业和城市的固体垃圾，进入水体中的废弃物，以及散撒使用流入到环境中的废弃物。

国内总输出（TDO），国内总输出是国内过程输出及隐性开采输出到环境的废弃物总和，这个指标表示了由于经济活动造成对环境废弃物的总量。

直接物资总输出（DMO），DMO 是 DPO 和出口量之和，这个指标表示在

离开社会经济活动之后所有再排放到国内环境的物资总量。

物资总输出（TMO），TMO 表示社会经济活动造成再排放到环境的物资总和，TMO 是 TDO 加上出口的总和。

（三）德国循环经济评价方法

物质流分析是指对经济活动中物质流动的分析，它的基础是对物质的投入和产出进行量化分析，建立物质投入和产出的账户，以便于进行以物质流为基础的优化管理。物质流分析主要衡量的是经济社会活动的物质投入、产出和物质利用效率，它属于生态经济系统定量评价方法中的物质量评价法的应用。循环经济强调从源头上减少资源消耗，有效利用资源，减少污染物排放。物质流分析是对循环经济的重要技术支撑，基于物质流分析的指标体系评价法是评价循环经济发展的重要方法。物质流分析研究从循环经济的角度，定量化地描述自然资源的消耗与人类经济活动的关系、废弃物的产生与人类经济活动的关系以及废弃物的再使用和资源化再生利用。

综合指数评价法是根据评价对象特点、评价目的要求抽取评价对象的典型性质参数构成评价指标，依据评价标准综合衡量系统状态优劣的一种综合指标体系评价方法。综合指数评价法是根据指数分析的基本原理，采用加权算术平均公式进行综合评价，采用每项指标的均值作为评价的标准，把量纲不同的指标化为可比的统计指数，从而使得指标具有可比性。其评价的步骤是：首先确定评价项目的权数，然后计算各子系统的综合平均指标，最后求出综合平均指数。

（四）经验借鉴

1、有针对性地进行专项立法

综观德国循环经济的发展可以看出，其立法具有较强的针对性。围绕物料回收利用这一重点，德国颁布了一系列专项法规，包括包装物、废弃汽车、电子设备、建筑垃圾、生活垃圾等领域的专项立法。这一系统性的专项法规的设立，使得德国在废弃物处理方面处于世界领先地位。结合我国循环经济发展的实际，我们除需制定基本法外，也需要有针对性、有重点地进行专项立法，并加大循环经济法律实施的力度，实现以点带面，为促进整体发展创造条件。

2、鼓励非政府组织介入

包装废弃物收集和处理的双元回收系统（DSD）模式是德国在循环经济实践中建立的典型模式。我国政府可以借鉴德国的双元回收系统模式，鼓励非政府

组织介入包装废弃物回收和利用行业，实现资源的再利用。非政府组织的介入将为企业发展循环经济提供更多的选择，同时能够帮助企业建立回收利用和资源化体系。

3、建立相应的监督机构

德国循环经济监督部门的建立，使循环经济措施得以在企业的生产和销售环节实施。我国在循环经济实施的过程中，政府除进行引导外，更重要的是在发展初期，给予企业一定的监督和指导，尽快促进循环经济走向正规化和常态化。在循环经济发展初期，企业出于降低成本的目的，不会自发开展循环经济实践，因此需要监管部门予以引导。参与循环经济实践的企业取得的成绩，需要监管部门予以评定。这也使得循环经济监督结构的建立成为必需。监督机构通过评估和反馈，为企业开展循环经济实践和提出改进措施提供引导和帮助，最终会保障国家循环经济实践的顺利开展。

三、日本循环经济评价指标体系及方法

（一）日本循环经济发展现状

“二战”后，日本经济高速增长，这使面积狭小、资源匮乏的日本更加体会到资源与环境的压力，随着本国废弃物由产业无公害治理向生活污染物防治的转变，日本政府适时地出台了一系列战略和规划，其战略意图在有计划的实施过程中不断得以实现。经过多年的努力，日本已成为循环经济发展较为成熟的国家之一，尤其是构建循环经济法律体系方面，其经验一直被各国所借鉴。

日本建立循环型社会的实践主要体现在三个方面：环保产业化，即发展“静脉”产业；产业环境化，即发展环境友好型“动脉”产业；“动脉”与“静脉”结合或联通，并趋向物质流动平衡。早在 2000 年，日本政府就颁布了《日本循环型社会形成推进基本法》，把建设循环型的可持续发展社会提升为日本经济社会的总体发展目标，目前日本已经建立了比较健全的循环经济法律法规体系，保障了日本循环经济的发展。

1、以法律保障循环经济体系的构建

从法律法规体系看，日本建立了较完备的循环经济法律法规体系，主要包括三个层次：以《日本循环型社会形成推进基本法》为主体的基本法；以《废弃物处理法》和《资源有效利用促进法》为主体的综合性法律；以《家电再生利用法》《汽车再生利用法》《建筑材料再生利用法》《包装容器再生利用法》《食

品再生利用法》《绿色采购法》为主体的专项法。其中，《日本循环型社会形成推进基本法》以建立“生产者-消费者-分解者”的产业经济链为基础，要求日本社会最终形成互利共生的循环经济网络，实现物质能量流的闭合式循环。

2、以经济政策为助力促进循环型社会的构建

为了促进循环型社会的发展，日本先后实施了一系列的经济政策。其中最主要且贯穿整个日本循环型社会构建的主线中的一项就是生态园补偿金制度。该项补偿金制度的主要内容是：环境省资助软件设施建设，经济产业省提供硬件设施，地方政府建设基础设施，涉及其他部门的项目，由主管部门支持。在六部专项法的执行过程中，日本也根据每部专项法的特点制定了详细的经济制度，保证废弃家电、汽车、包装材料、建筑物等能够更好地实现回收再利用[5]。

（二）日本循环经济评价指标体系构成

日本在推进循环经济发展上，走在世界的前列。在建立循环经济法律体系的基础上，明确制定出循环型社会推进计划，并采用物质流分析方法制订了具体的发展目标。日本通过物质流分析方法对日本1980-2000年的国内宏观物质流动进行了分析，基本完善了循环经济指标。初始时，日本从资源的投入、生产、消费以及最终废弃处置等过程提出了六项循环经济指标，其中：。

表 2-3　日本物质流指标体系

类型	指标
物质循环利用	直接物资投入量
	直接物资输出量
投入和输出	废弃物的再资源化率
	废弃物的循环利用率
生产和消费	资源的利用效率
	资源的利用时间

直接物资投入量和直接物资输出量两个指标用于评价，通过促进物质循环利用使得自然资源开采量的减少以及环境负荷的降低；

废弃物的再资源化率和废弃物的循环利用率两项指标用于从投入和输出两方面对废弃物的循环利用率进行评价；

资源的利用效率和资源的利用时间将生产和消费各个关节的资源“有效利用”程度表示出来。

日本通过多年对 MFA 方法和循环经济的研究，最终确定了其中的 3 个指标作为核心的循环经济指标。这三个指标分别为：（1）资源生产率，日本将直接物资投入量指标结合经济指标修改为资源生产率指标，即当年本国 GDP 与直接物资投入量的比值。（2）废弃物的循环利用率，废弃物的循环利用率不仅包括消费后废弃物的循环再利用，还包括生产过程中对生产过程产生的废弃物的循环利用。（3）废弃物最终处置量，日本将直接物资输出量范围缩减到废弃物最终处置量，这部分包括工业垃圾以及城市垃圾经过最终处置后排入自然界的量。其他的指标包括“废弃物的再资源化率”，为各个部门作为部门内每种产品的目标进行设定；“资源的利用效率”和“资源的利用寿命”还有待资料的积累和研究。

（三）日本循环经济评价方法

物质流分析法是指在一定时空范围内关于经济系统的物质流动和贮存的系统性分析，主要涉及的是物质流动的源、路径及汇。根据质量守恒定律，物质流分析的结果总是能通过其所有的输入、贮存及输出过程来达到最终的物质平衡。这是物质流分析的显著特征，它为资源、废弃物和环境的管理提供了方法学上的决策支持工具。20 世纪 90 年代初，奥地利、日本和德国首先应用物质流分析方法对各自国家经济系统的自然资源和物质的流动状况进行了分析，从而就揭开了经济系统物质流分析方法在世界范围广泛应用的序幕[9]。

费用效益法，它是按照资源合理配置的原则，从国家整体角度考察项目的费用和效益，以影子价格为主要思路，辅助使用影响法，用货物影子价格、影子工资、影子汇率和社会折现率等经济参数，分析、计算有关项目对国民经济的净贡献和评价项目的经济合理性。费用效益分析是通过项目建设及实施所必要的建设投资等费用与其所产生效益之间的对比，以提高社会经济效率性为准则，对项目可行性做出分析的过程。影子价格，又称为效率价格，实质上是经济资源内在的价值含量，是保证资源最优化利用而体现的价格，是费用效益分析核心手段。费用效益分析通过对生态环境影响进行价值评估，从而把人们对环境的关注纳入到项目的可行性研究中，它是建立在循环经济效益分析和开发项目的环境影响评价之间的桥梁。

（四）经验借鉴

我国在经济高速增长时期所经历的环境问题与日本快速发展时期有很多相似之处。我国目前城市生活垃圾的无害化处理率仅为 6%，有 300 多个城市陷入

垃圾的包围中。日本环境治理的历程，特别是日本构建循环型经济社会的实践，对于我们探索中国特色循环经济实践模式具有重要参考价值。第一，相关法律法规的制定是发展循环经济的基本前提，法律的健全能够促进企业、公众参与发展循环经济；第二，机制建设应与社会构建同步推进，完善的运行机制和可靠的体制建设是构建循环型经济社会的保证。

四、国内循环经济评价指标体系及方法

（一）国内循环经济发展现状

20 世纪 90 年代末以来，我国引入循环经济理念后，引起学术界和决策层在理论研究及实践领域的关注。自 2002 年以来，循环经济研究文献如雨后春笋，迅猛增长。2005 年，国务院下发了《关于加快发展循环经济的若干意见》，确立了我国发展循环经济的指导思想、基本原则和主要目标，加快发展循环经济已经成为贯彻和落实科学发展观，全面建设小康社会、实现可持续发展的重大战略举措。经过多年探索，我国关于循环经济的研究已由理念传播、概念诠释阶段发展到理论体系建构阶段，并取得多方面的成果。2013 年，国务院发布了《循环经济发展战略及近期行动计划》，这是我国首部国家级循环经济发展战略及专项规划，针对循环经济发展的重点、难点、热点，在思路、内容、体制、机制上提出了很多创新点。

从 1999 年开始，国家环保总局在研究和借鉴国际上发展循环经济经验和做法的基础上，从解决工业污染和城市污染入手，通过推动清洁生产、建立生态工业园、建设循环经济型社会等多种模式，从企业、区域和社会多个层次进行了循环经济理论的探索和实践的尝试。2003 年，国家环保总局进一步将生态工业理念引入工业门类齐全、经济综合性强的各类经济开发区、高新区等，在工业园区广泛开展生态工业园区建设工作，使得我国生态工业园区的建设进入了一个新的阶段。

近年来，我国在三个层次上逐渐展开循环经济的实践探索，并取得了显著成效：

在小循环层面，积极推行清洁生产。我国是国际上公认的清洁生产搞得最好的发展中国家。2002 年我国颁布了《清洁生产促进法》。目前我国已在 20 多个省（区、市）的 20 多个行业企业开展了清洁生产审计，建立了 20 个行业或地方的清洁生产中心，1 万多人次参加了不同类型的清洁生产培训班。有 5000 多

家企业通过了ISO14000环境管理体系认证，几百种产品获得了环境标志。

在中循环层面，按照循环经济理念建立由共生企业群组成的生态工业园区。在企业相对集中的地区或开发区，建立生态工业园区。这些园区都是根据生态学的原理组织生产，使上游企业的“废料”成为下游企业的原材料，尽可能减少污染排放，争取做到“零排放”。如贵港国家生态工业园区、南海国家生态工业园区、衢州沈家生态工业园区、天津经济技术开发区生态工业园区和烟台开发区生态工业园等等。

在城市和省区开展循环经济试点工作方面，目前已有辽宁、贵阳和青海等省市开始在区域层次上探索循环经济发展模式。辽宁省在老工业基地的产业结构调整中，全面融入循环经济的理念，通过制订和实施循环经济的法律和经济措施体系，建设一批循环型企业、生态工业园区、若干循环型城市和城市再生资源回收及再生产业体系，充分发挥当地的资源优势和技术优势，优化产业结构和产业布局，推动区域经济发展，创造更多的就业机会，促进经济、社会、环境的全面协调发展。贵阳颁布了我国第一部循环经济法规，为推进循环经济建设提供了法律保证。青海省立足盐湖、油气、煤炭、有色金属等资源优势，按照建设国家循环经济发展先行区的目标，坚持把发展循环经济作为转变发展方式的主攻方向，产业框架初步构建，产业链条不断延伸，园区示范带动明显，基础设施逐步完善，科技支撑显著增强。广东、浙江、上海等在地方经济的发展过程中开始重视经济发展中资源消耗、社会公平和人的发展等问题。“十二五”时期中国实施循环经济10大工程，创建100个循环经济示范城市，培育1000家循环经济示范企业，推动循环经济形成较大规模。

此外，广东省编制了珠江三角洲环境保护规划，提出了“以人为本，环境优先”的指导思想，确定了优化社会经济布局、发展循环经济和防治环境污染的红线、绿线和蓝线“三线战略”。浙江省也提出要建设以循环经济为核心的生态经济体系。上海是最先开始循环经济发展战略研究的城市，已经把有关循环经济的概念和思想纳入到《中国21世纪议程——上海行动计划》，制定了上海市的循环经济发展战略与实施计划，提出建设循环经济型的国际大都市的构想。同时，江苏、山东、黑龙江、甘肃等省市也都在积极推动循环经济发展。循环经济已经从工业与环境保护领域逐步扩展到整个社会经济的各个领域。

（二）国内循环经济评价指标体系构成

1、社会层面循环经济评价指标体系的研究

社会层面循环经济评价体系是对区域社会、经济、生态环境系统协调发展状况进行综合评价与研究的依据和标准，是综合反映社会、经济、生态环境系统不同属性的指标按隶属关系、层次关系原则组成的有序集合。国家环保总局政研中心周国梅和清华大学刘滨在对物质流分析和物质流管理的国家经验方法上进行研究,从物质利用总量和强度两个方面分析了物质流分析和物质流管理与循环经济的密切关系，并提出了评价指标体系[10]。

循环经济评价指标体系的研究，也引起了国家的高度重视。由中科院副院长段宁负责，在国家环保总局局长解振华直接关心下的国家科技攻关计划课题“循环经济理论生态工业技术研究”中的子课题 3 就是关于循环经济和生态工业指标及规划指南。

全国人大环资委、上海人大常委会通力合作，组织有关部门和单位的专家学者，成立了中国循环经济理论和方法课题组。以冯之浚为组长的课题组对循环经济评价指标体系进行了初步的探索，把循环经济分为经济、社会和生态环境三个子系统的循环分别进行评价[11]。

天津社会科学院的牛桂敏（2005）依据循环经济的内涵和目标，遵循循环经济评价指标体系的构建原则，对循环经济评价体系的构建进行了研究，在现行国民经济统计指标体系的基础上增加了反映经济社会活动中的物质投入、排放、利用效率和循环利用方面的指标[12]。

2007 年，国家发改委、环保总局、统计局等联合编制发布了《循环经济评价指标体系》，从资源产出、资源消耗、资源综合利用和废弃物排放 4 个方面入手，在宏观层面上规定了 22 个循环经济评价指标。资源产出指标主要是指消耗一次资源所产生的国内总产值，该项指标越高，表明自然资源利用效益越好。资源消耗指标主要描述单位产品或创造单位 GDP 所消耗的资源，该类指标反映了节约降耗，推进“减量化”，从源头上降低资源消耗的情况。资源综合利用指标主要反映工业固体废物、工业废水、城市生活垃圾等废物的资源化程度以及反映传统的五大类废旧物资的回收利用状况，体现了废物转化为资源、节约使用资源、循环利用资源的要求，即“资源化”的成效。废弃物排放指标主要用于描述工业固体废物、工业废水、二氧化硫和 COD 的最终排放量，该类指标反映了通过减量化、再利用和资源化，从源头上减少资源消耗和废物产生，降低废物最终排放量、

减轻环境污染的成果。

表 2-4　循环经济评价指标体系宏观层面

类型	指标	类型	指标
资源产出	主要矿产资源产出率	资源消耗	单位国内生产总值消耗
	能源产出率		单位工业增加值消耗
资源综合利用	工业固体废物综合利用率		重点行业主要产品单位综合能耗
	工业用水量重复利用率		单位国内生产总值用水量
	城市污水再生利用率		单位工业增加值用水量
	城市生活垃圾无害化处理率		重点行业单位产品水耗
	废钢铁回收利用率		农业灌溉水有效利用系数
	废有色金属回收利用率		工业固体废物处置量
	废纸回收利用率		工业废水排放量
	废塑料回收利用率		二氧化硫排放量
	废橡胶回收利用率		COD 排放量

2、园区层面循环经济评价指标体系的研究

生态工业园区是循环经济的一种重要表现形式。我国 1999 年建立了第一个国家生态工业园，该园区产业各环节实现了充分的资源共享，变污染负效益为资源正效益。目前对生态工业园区的研究主要侧重于园区建设的理念思路和生态规划，对生态工业园区的评价指标体系研究得不多。国家清洁生产中心元炯亮（2003）对生态工业园区的评价指标体系进行了研究，提出了生态工业园区评价指标体系的框架，包括经济指标、生态环境指标、生态网络指标和管理指标。经济指标由反映当前经济发展水平和反映经济发展潜力的指标组成；生态环境指标包括环境保护、生态建设和生态环境改善潜力等方面；生态网络指标是工业生态园区的特征指标，反映物质集成、能量集成、水资源集成、信息共享和基础设施共享的效果；管理指标包括政策法规制度、管理与意识等[13]。2007 年，国家发改委、环保总局、统计局等联合编制发布了《循环经济评价指标体系》，从资源产出、资源消耗、资源综合利用和废弃物排放 4 个方面入手，在工业园区层面上规定了 14 个循环经济评价指标。资源产出指标包括：主要矿产资源产出率、能源产出率、土地产出率、水资源产出率。资源消耗指标包括：单位生产总值能耗、单位

生产总值用水量、重点产品单位能耗、重点产品单位水耗。资源综合利用指标包括：工业固体废物综合利用率、工业用水重复利用率。废物排放指标包括：工业固体废物处置量、工业废水排放量、二氧化硫排放量、COD排放量。生态工业园区评价指标主要用于定量评价和描述园区内循环经济发展情况，为生态工业园区发展循环经济提供指导。

3、企业层面循环经济评价指标体系的研究

关于企业循环经济评价指标体系的研究目前还比较缺乏。南开大学经济学院李健等（2004）对面向循环经济的企业绩效评价指标体系的结构及其评价方法进行了研究。李健认为在评价企业绩效的时候，应综合考虑经营效果、绿色效果、能源属性、生产过程属性、销售和消费属性、环境效果和发展潜力七个方面对企业的影响，并分别为每个方面设定对应的评价指标，从而构成一个多目标评价指标体系[14]。陈勇等（2009）认为钢铁行业是我国发展循环经济的试点行业，研究钢铁企业循环经济发展水平的评价指标体系，不仅是指导钢铁企业更好发展循环经济的现实要求，而且是加快我国循环经济发展的客观需要。因此他参照国土资源部《矿产资源领域循环经济评价指标体系研究报告》、国家发改委等《钢铁行业清洁生产评价体系（试行）》等指标体系，以攀钢为背景构建了钢铁企业循环经济发展水平评价指标体系[15]。刘传庚等（2009）认为发展循环经济是构建和谐矿区，实现矿区可持续发展的必然选择，以西山公司为背景构建了煤炭企业循环经济综合评价指标体系[16]。

（三）国内循环经济评价方法

实现循环经济是一个动态的、综合的过程，因此，对一个地区循环经济的发展水平进行评价实际上是一个多指标综合评价的过程。在综合评价实践中可运用多种确定指标权重的方法，用比较多的方法有Delphi法、层次分析法、成对因素比较法以及统计分析法等。于丽英、冯之浚等（2005）选用主观赋值法，最常用的主观赋值法即为Delphi法，又称专家意见咨询法，实际中为了确定某个指标的权重，可向许多专家咨询，并对返回结果进行综合处理，再次返回专家咨询意见，如此反复，直至所有专家已对此指标的权重达成基本一致[11]。向来生等（2007）选用主客观赋值法，此法中以层次分析法为典型代表。层次分析法是一种定性与定量相结合的决策分析方法。决策者通过将复杂问题分解成若干层次和若干因素，在各因素之间进行简单比较和计算，即可得到指标权重[17]。田金方等

（2007）提出，为了避免认为确定权重的主观性，利用主成分分析确定指标的权重，进而得到循环经济综合评估模型。主成分分析就是利用降维的思想从较多的指标中找出较少的几个综合指标，而这些指标能较好地反映原来资料的信息[18]。庞庆华等（2012）研究了面向循环经济的企业绩效评价指标体系的设置，认为面向循环经济的企业绩效评价的外部表现应该是多维的，其追求的目标也应该是多元的。所以，面向循环经济的企业绩效评价是一个多层次、多因素、多目标的综合评价。将模糊理论与层次分析法相结合，建立模糊综合评价数学模型，并运用这种评价方法对企业绩效进行量化考评[19]。冯艳（2007）提出采用客观赋值法，其中差异驱动法来确定指标的权重，能保证权重赋值不受人为主观因素的影响。关联度作为一种技术方法，用于分析系统中各种因素的关联程度，其基本思想是根据曲线间的相似程度来判断关联程度，关联度越大则说明两者之间的相对变化基本一致；反之，则认为两者之间的变化差异较大。利用灰色关联度分析，既可以对不同时段循环经济建设的状况进行纵向比较分析，考核规划目标的完成效果和达标情况，也可以对不同区域循环经济建设的状况进行横向比较分析[20]。

（四）国内外循环经济评价比较分析

随着循环经济在国内外实践不断深入，衡量循环经济发展水平则成为循环经济研究中的一个重要领域。许多学者从不同角度对循环经济评价进行了大量的研究，综合国内外的研究情况可以发现，虽然国内对于循环经济研究开始较早，但对这种经济发展模式本身的理论研究仍处于探索阶段，目前基本上侧重于在具体领域的应用和实现手段的研究，且这些研究大多数是基于本身实际情况进行的，如美国的杜邦模式、德国的双元回收系统模式均缺乏系统性的理论升华。广泛应用的 MFA 方法需要有较为系统的物质流数据基础，而实际统计中这方面的数据较为缺乏，这在一定程度上限制着该方法的应用和发展前景。

我国对循环经济的研究主要集中在对循环经济基本理论和实现方式的探讨上，循环经济评价方法与其他领域的指标评价方法基本一致，缺乏对循环经济特征的方法改进的研究。尽管很多学者对循环经济评价进行了许多相关的研究，但仍存在一些问题，还需要在以后理论与实践的探索中不断改进。主要有：

（1）针对循环经济系统的评价指标体系及评价方法的研究成果较少，主要集中于个别案例的评价指标体系研究较多，缺乏一套广泛适用的循环经济评价指标体系，研究者普遍满足于给出一系列的指标构成指标体系，而对指标与循环经

济的内在联系，必然的或偶然的，解释得不充分。这与评价者的知识水平、背景、认识问题的角度、价值观念，尤其是目标理解等方面的不同是密切相关的。

（2）指标过于庞杂且不均衡。各类指标对循环经济发展的作用和影响程度是不一样的，在指标的选用上，指标过于庞杂且不均衡，研究者详细列出了各种可能的指标，数量巨大，而且其中能够反映循环经济发展的动态指标偏少。

（3）循环经济发展的评价主要使用层次分析法等传统评价方法。虽然层次分析法非常适合多目标、多因子、多层次的复杂系统的决策和评价，但由于指标的权重确定选用的是定性与定量相结合的方式，故其准确性在一定程度上受人为因素的影响。

（4）数据来源短缺，统计方法不统一。由于评价指标体系的复杂性和综合性，所以它就需要多种数据来支持被选定指标的合理性和可行性，故数据的来源非常重要。但就目前来说，数据来源短缺，有些重要数据只能靠估计。另外，由于统计指标的类型与特点不同，造成现有的统计方法不统一。

（5）缺乏实证对指标体系的合理性的检验。很少见到能将指标构建、评价模型和实证研究集于一体的研究成果，因而指标体系难以投入实际应用，很多只在学术界理论探讨。

（6）社会层面循环经济评价指标体系的研究过多，企业层面上的研究比较少。对核心产业和各类产业或企业间具有产业关联度或潜在关联度的研究具有重要意义，而在这方面我国的相关研究还限于园区设计，且园区内核心产业及产业关联度的评价指标还不完善。

第三章　循环经济评价指标体系设计

一、循环经济评价指标体系设计原则

（一）梳理国内外文献

目前，以美、德、日等发达国家为代表的循环经济发展实践已经得到了一定的社会效益，使人们越来越认同循环经济是实现可持续发展的必然选择。其他国家或地区也纷纷开始效仿，将发展循环经济纳入实际操作层面，在编制总体规划、区域规划、城市规划以及专项规划时，都把发展循环经济放在重要战略位置。

国外对循环经济评价指标体系的研究多集中于20世纪90年代，可分为以下4个方面：一是在已有的社会发展评价指标体系的基础上提出体现循化经济思想的新型指标；二是构建可持续发展指标体系；三是基于物质流分析的循环经济评价指标体系；四是从生态效率角度研究循环经济的评价指标体系。国内学者对于区域循环经济评价指标体系的研究多集中于3个方面：一是企业层面上，二是工业园区层面上，三是区域层面上。社会层面循环经济评价指标体系的研究比较丰富，工业园区和企业层面的研究相对缺乏。

从循环经济评价指标体系研究的演进过程看，无论国内、国外，每一时期的循环经济综合评价都是由于社会、经济、环境的变化而不断发展变化的。发展循环经济的目的是要实现经济增长与资源、环境、生态的相互协调，用最少的资源消耗和最小的环境代价，实现最大的经济和社会效益。建立循环经济评价指标体系，有助于政府作为宏观经济的调控者从宏观管理层面上制定循环经济发展目标、计划、战略，并对循环经济运行效果和发展水平进行判断。因此，根据当地情况和循环经济的内涵和理念，构建合理的循环经济评价指标体系，可以为制定循环经济发展的规划、目标、具体措施等提供理论依据和参考指标，并为监督、考核、评价循环经济发展效果提供定量评价工具，使政府在循环经济发展的宏观调控管理中既能发挥政策引导作用，又能提供具体的技术指标和参数，使循环经济的发展有科学依据。

（二）指标体系设计原则

循环经济发展评价指标的选取应考虑经济—环境—生态—社会等诸多要素，构成完整、全面的指标体系。指标选取要符合以下标准[21]。

（1）体现“3R”原则。循环经济发展指标体系的本质就是要反映循环经济“3R”原则的应用情况以及实施效果，所以其指标的选取一定要突出体现“3R”原则在整

个指标体系中的核心地位和重要作用。

（2）层次性与系统性相结合。循环经济的发展具有鲜明的层次性，就一个国家来说，有地区、城市、行业、企业之分；就循环经济的发展系统来说，又分为经济、生态、环境、社会等多个子系统，而各子系统内部还有更具体的层次。因此，评价指标体系应该兼顾层次性和系统性。

（3）整体性与相关性相结合。循环经济的发展是一项复杂的系统工程，指标体系是一个有机整体，指标选取不但应该分为不同的子系统，从各个不同角度反映被评价系统的主要特征和状况，而且需要从整个循环经济发展的大系统角度出发，将生态环境、社会经济发展等诸多方面作为一个整体来考虑。

（4）水平指标和结构指标相结合。水平指标又称绝对指标，能够反映经济社会现象总体规模和水平，结构指标又称相对指标，常用来反映经济社会现象之间数量联系程度。单一使用水平指标或者结构指标都有其弊端，将水平指标和结构指标有效地结合起来，才能深刻、全面反映当前循环经济的发展状况。

（5）静态指标与动态指标相结合。构建循环经济发展水平评价指标体系的目的不仅是为了评价循环经济的发展状况，更重要的是为了对循环经济的未来趋势进行预测。因此，评价指标体系中既要有反映循环经济现有规模和发展水平的静态指标，又要有能综合反映循环经济系统的动态变化特点和发展趋势的指标。

（6）科学性与可操作性相结合。指标体系的科学性体现在，各项指标能对循环经济系统各层次、各环节的物质、资金、要素等投入产出进行高度的抽象和概括，揭示其性质、特点、关系以及运动过程中所遵循的内在规律。但与此同时，指标体系中的指标表征内容要简单明了，要考虑指标量化和数据取得的难易程度等问题，尽可能提高可操作性。

（7）可比性与可靠性相结合。评价指标体系应具有动态科比和横向可比的功能。动态可比是指一个地区循环经济发展水平在时间序列上的动态比较；横向可比是指不同地区在同一时间上对综合评价指标数值的排列比较，说明各地区循环经济发展的不平衡程度。同时，统计指标的选择应涵义明确，口径一致，与国际惯例接轨，符合国际规范和国内现行统计制度的要求，以保证统计数据的可靠性。

二、循环经济评价指标体系设计

（一）指标体系初选

目前我国对于循环经济评价指标体系的构建尚处在研究阶段，还没有一套完善的评价指标体系，因此，在构建循环经济评价指标体系时就必须借鉴目前已经比较成熟的指标体系。同时评价指标体系的设计要依据循环经济发展的内涵、目标和原则，充分考虑影响循环经济发展的各种因素，在分析系统结构、层次结构的基础上，结合循环经济评价指标体系的设计原则等初步选择具体的评价指标，建立预选的评价指标体系。

2007 年，为贯彻落实《国务院关于加快发展循环经济的若干意见》（国发[2005]22 号），科学评价我国循环经济的发展状况，为制定和实施循环经济发展规划提供数据支持，促进循环经济发展，建立资源节约型、环境友好型社会，国家发改委、环保总局、统计局等联合编制了《循环经济评价指标体系》，包括社会层面和工业园区层面。社会层面规定了 22 个循环经济评价指标，用于对全社会和各地发展循环经济状况进行总体的定量判断，为制定和实施循环经济发展规划提供依据。资源产出指标包括：主要矿产资源产出率、能源产出率。资源消耗指标包括：单位国内生产总值消耗、单位工业增加值消耗、重点行业主要产品单位综合能耗、单位国内生产总值用水量、单位工业增加值用水量、重点行业单位产品水耗、农业灌溉水有效利用系数。资源综合利用指标包括：工业固体废物综合利用率、工业用水量重复利用率、城市污水再生利用率、城市生活垃圾无害化处理率、废钢铁回收利用率、废有色金属回收利用率、废纸回收利用率、废塑料回收利用率、废橡胶回收利用率。废物排放指标包括：工业固体废物处置量、工业废水排放量、二氧化硫排放量、COD 排放量。

2013 年，为进一步推进循环经济发展，青海省委省政府印发《青海省建设国家循环经济发展先行区行动方案》（青发[2013]20 号）。文件指出建设国家循环经济发展先行区是青海转变经济发展方式的战略举措、实现可持续发展的战略选择、提高地区经济竞争力的强力抓手，为此必须从构建循环型工业体系、循环型农业体系、循环型服务业体系、循环型社会入手。为了切实反映循环经济的发展状况，文件还规定了 22 个主要指标。具体包括：循环经济工业增加值占比、主要资源产出率提高、工业用水重复利用率、工业固体废物综合利用率、可再生能源占能源生产比重、生态保护区占国土面积比重、水环境质量、电解铝综合交流电耗、畜牧业增加值占一产比重、秸秆综合利用率、农业灌溉用水有效利用系数、沼气普及率、农畜产品加工转化率、绿色建筑占当年新增民用建筑比例、城

市餐厨废弃物收运处理率、科技进步对经济增长的贡献率、大中型企业和创新型企业研发经费占主营业务收入的比例、单位GDP能耗下降、二氧化硫排放量、COD排放量、氮氧化物排放量、氨氮排放量。

综合来看，上述指标体系偏重于资源环境方面，而循环经济发展的最高宗旨是在生态可持续条件下实现人类社会经济发展不断进步，循环经济一个涉及经济、社会、资源环境多方面协调、综合发展的整体，其发展的最终目标是实现经济、社会和资源环境的共赢发展。杨华峰等（2005）认为循环经济是集经济、社会和环境于一体的系统工程，将循环经济评价指标体系分为经济系统、社会系统、生态环境系统三个部分[22]。郗永勤等（2013）著的《循环经济发展的机制与政策研究》中，认为循环经济发展现状不仅与能够直接体现循环经济发展特征的某些指标相关，而且与经济发展、社会发展（包括科技、教育）等情况密切相关，因此从循环经济特征子系统和社会、经济支撑子系统的角度构建了四级评价指标体系框架[5]。

本文在参照上述循环经济评价指标体系的基础上，通过查阅和收集国内外现有的统计资料、统计指标和统计信息，如各种年鉴、手册、专著、论文、报告等，运用频度统计法、理论分析法和专家分析法等方法建立循环经济评价的一般指标体系。频度分析法主要是对收集的目前循环经济评价研究的论文、报告等进行频度统计选择那些使用频度较高的指标；理论分析法主要是对循环经济的内涵、特征基本要素、主要问题进行分析、比较、综合，选择那些重要性强和针对性强的指标；专家咨询法是在初步提出评价指标的基础上，进一步征询有关专家意见，对指标进行调整。

（二）指标体系筛选及优化

指标体系的初选过程虽然已经构建了一个指标体系，但指标体系的科学性、合理性、实用性又是获得正确结论的基础和前提条件。为了保证其科学性，在指标体系的初选完成以后，还必须有针对性地对其科学性进行检验，即对初选指标体系进行完善化处理，包括单体检验和整体检验。

1.单体检验是检验每个指标的可行性和正确性。可行性主要是检验单体指标的符合实际情况，分析指标数值的可获得性；正确性分析是对指标的计算方法、计算范围及计算内容的正确与否进行的分析。

2.整体检验是对指标体系的指标的重要性、必要性和完整性进行的检验。重

要性的检验是根据区域特征来分析应保留哪些重要指标,剔除那些对评价结果无关紧要的指标。一般利用德尔菲法对初步拟出的指标体系进行匿名评议。必要性的检验是对所拟出的评价指标从全局出发考虑是否都是必不可少的,有无冗余现象。完整性的检验是对评价指标体系是否全面、毫无遗漏地反映最初描述的评价目的与任务。

在评价指标优选后，还要通过专家型咨询法、主成分分析和独立性分析等把所得的指标进行进一步筛选。专家咨询法是在初步提出评价指标的基础上，进一步征询有关专家意见,对指标进行调整;主成分分析法是通过恰当的数学变换，将一系列指标重新组合成一组新的互相无关的几个综合指标来分析事物的一种多元统计分析方法，能够尽可能多地反映原来指标的信息；独立性分析是来验证各指标是否具有相关性，删除一些不必要的指标，简化评价指标体系。通过以上筛选,选择内涵丰富又相对独立的指标,最终构成具体的循环经济评价指标体系。

三、循环经济评价指标体系总体框架、释义及计算

（一）指标体系总体框架

本文分别从经济系统、社会系统、资源环境系统三方面构建循环经济发展水平综合评价的四层指标体系结构，目标层—系统层—准则层—指标层，具体如下：

1、目标层

循环经济发展水平综合评价的总体目标是在循环经济模式下，整个区域内的经济、社会、资源和环境效益协调发展，目标层由系统层加以反映。

2、系统层

循环经济是一个复杂的系统，是兼顾经济社会发展、节约资源和保护环境的一体化战略，因此，为了评价的展开与进行，可以将这个大系统分解为更小的系统。通过阅读大量的国内外相关文献，将循环经济系统分成经济系统、社会系统和资源环境系统三个子系统。这样不仅可以整体考察循环经济的综合运行状况与发展水平，把握循环经济的宏观走向，还可以评价各个子系统，把握各个子系统的运行情况。

3、准则层

在上一步中已经确立了各个子系统，接下来对每个子系统作进一步的细分。在进行细分的过程中，往往需要从不同的角度去进行分析。将经济系统分为水平

指标与结构指标，以此反映循环经济的经济总量水平和经济结构水平。在社会系统中，从人居环境、社会进步和科学教育三个角度对其进行分解。在资源环境系统中，所依据的是循环经济中最为核心的3R原则，即“减量化、再利用、资源化”原则。对三个子系统进行细分后还没有到具体的、可以衡量的指标，因此需要做进一步的分解。

4、指标层

整个指标体系的基础层，准则层的各准则通过指标层的具体指标说明。该层的设计上应该选择那些可测的、可比的、具有代表性、独立性较大的指标作为评价指标。同时要尽可能利用现有的统计指标数据，既节省资源，方便数据的收集，保证数据的可靠性，又达到综合评价的目的。本文指标层由32个指标组成，具体指标框架如表3-1所示。

（二）指标释义

地区生产总值增速（%）：是指按不变价格计算，把当年地区生产总值换算成按某个基期价格计算的价值，使两个不同时期的价值可比，真实反映其变化程度。它是反映一个地区经济水平动态变化和发展趋势的重要指标，指标数值越大，表示该地区的经济发展越具有活力。

人均地区生产总值（元/人）：是指地区生产总值与该地区常住人口的比值，即每个居民所创造的地区生产总值。它是最常用也是最重要的宏观经济指标之一，可以衡量一个地区人民生活水平的高低，指标数值越大，反映该地区的经济发展状况越好，越能为循环经济的发展提供足够的物质基础。

表3-1　循环经济评价指标体系

目标层	系统层	准则层	指标层	性质
循环经济发展水平	经济系统	经济水平	地区生产总值增速X1	↑
			人均地区生产总值X2	↑
			人均财政收入X3	↑
			人均消费品零售额X4	↑
		经济结构	第三产业增加值占GDP比重X5	↑
			社会固定资产投资占GDP比重X6	↑
			城镇化水平X7	↑
	社会系统	人居环境	人均公园绿地面积X8	↑
			建成区绿化覆盖率X9	↑

			人均城市道路面积 X10	↑
			每千人的私人汽车拥有量 X11	↓
		社会进步	城镇居民人均可支配收入 X12	↑
			社会保障支出占财政支出比重 X13	↑
			医疗卫生支出占财政支出比重 X14	↑
			每千人的公共汽车拥有量 X15	↑
		科教文体	R&D 经费投入强度 X16	↑
			教育支出占财政支出比重 X17	↑
			每十万人口中高等学校在校学生数 X18	↑
			人均文化体育支出 X19	↑
	资源环境系统	减量化	单位 GDP 综合能耗 X20	↓
			单位 GDP 电耗 X21	↓
			单位 GDP 水耗 X22	↓
			环境治理投资占 GDP 比重 X23	↑
			单位 GDP 废水排放量 X24	↓
			单位 GDP 化学需氧量排放量 X25	↓
			单位 GDP 氨氮排放量 X26	↓
			单位 GDP 二氧化硫排放量 X27	↓
			单位 GDP 氮氧化物排放量 X28	↓
			单位 GDP 工业固废产生量 X29	↓
		再利用与资源化	农村沼气每人拥有量 X30	↑
			城市工业用水重复利用率 X31	↑
			城市污水日处理能力 X32	↑
			工业固废综合利用率 X33	↑
			城市生活污水集中处理率 X34	↑
			生活垃圾无害化处理率 X35	↑

人均财政收入（元/人）：是指财政总收入与该地区常住人口的比值。一个地区的财政收入和经济增长存在相互影响相互促进的依存关系，地区经济的发展需要有充足稳定的财政收入作后盾。人均财政收入关系到地区社会经济的发展和人民生活水平的提高，指标数值越大，说明该地区的经济越具有可持续发展的潜力。

人均消费品零售额（元/人）：是指社会消费品零售总额与该地区常住人口的比值。社会消费品零售总额是表现国内消费需求最直接的数据，是反映国内零

售市场变动情况、经济景气程度的重要指标。人均消费品零售额反映一定时期内人民物质文化生活水平和社会商品购买力的实现程度。

第三产业增加值占GDP比重（%）：是指第三产业增加值在地区生产总值中所占的比重。它是一个产业结构优化指标，第三产业包括流通部门和服务部门，主要是低能耗、低污染的产业，指标数值越大，说明循环经济的发展能力越强，社会的发达程度越高。

社会固定资产投资占GDP比重（%）：是指社会固定资产投资在地区生产总值中所占的比重。社会固定资产投资是以货币表现的建造和购置固定资产活动的工作量，综合反映固定资产投资的规模和使用方向。而社会固定资产投资占GDP比重是一个结构指标，反映固定资产投资的速度和比例关系，该指标可以反映地区经济增长的情况。

城镇化水平（%）：是指一个地区居住在城镇中的人口占城乡总人口的比例。它反映了人口向城市集聚的过程和集聚程度，是衡量一个地区经济发展程度的重要标志，指标数值越高，说明该地区的经济发展潜力越大，发展动力越强。

人均公园绿地面积（平方米/人）：是指城市公园绿地面积的人均占有量。城市公园绿地是城市建设用地、城市绿地和城市市政公用设施的重要组成部分，是展示城市整体水平和居民生活质量的一项重要指标。指标数值越大，说明该地区的绿化条件越好，也就越适宜人们居住。

建成区绿化覆盖率（%）：是指在城市建成区的绿化覆盖面积占建成区面积的百分比。绿化覆盖面积是指城市中乔木、灌木、草坪等所有植被的垂直投影面积，建成区绿化覆盖率越高，说明该地区的绿化条件越好，也就越适宜人们居住。

人均城市道路面积（平方米/人）：是指城市非农业人口平均每人所拥有该地区的道路面积。该指标最能综合反映一个地区交通的通畅水平，人均道路面积越多，说明该地区的交通状况越好，也就越适宜人们出行和居住。

每千人的私人汽车拥有量（辆/千人）：是指私人汽车拥有量与该地区常住人口的比值。私人汽车的普及虽然给人们的出行提供了便利，但随着私人汽车拥有量的快速提升，对地区环境、交通等造成了较大压力。每千人的私人汽车拥有量越大，对人居环境产生的负面影响越大。

城镇居民人均可支配收入（元/人）：是指平均每个城镇居民可用于最终消

费支出和储蓄的总和，即城镇居民可用于自由支配的收入。该指标被认为是城镇居民消费支出的最重要的决定性因素，常被用来衡量一个地区居民生活水平的发展情况。

社会保障支出占财政支出比重（%）：是指社会保障支出在财政总支出中所占的比重。社会保障支出是指政府通过财政向由于各种原因而导致暂时或永久性丧失劳动能力、失去就业机会或生活面临困难的社会成员提供基本生活保障的指出。社会保障支出占财政支出比重越大，说明社会公平程度和社会福利程度越高。

医疗卫生支出占财政支出比重（%）：是指医疗卫生支出在财政总支出中所占的比重。医疗卫生支出包括卫生管理事务支出、医疗服务支出、医疗保障支出、疾病预防控制支出、卫生监督支出、妇幼保健支出、农村卫生支出等。医疗卫生支出占财政支出比重越大，说明社会福利程度和社会进步水平越高。

每千人的公共汽车拥有量（辆/千人）：是指公共汽车拥有量与该地区常住人口的比值。公共交通尤其是公共汽车的快速增长对于缓解城市交通压力、改善城市居住环境、优化人们出行方式起着重要作用，在很大程度上体现了社会进步。每千人的公共汽车拥有量越大，说明社会进步水平越高。

R&D 经费投入强度（%）：是指全社会 R&D 经费支出与地区生产总值之比。它是国际上通用的反映一个地区科技投入水平的核心指标，高水平的 R&D 经费投入强度被认为是提高地区自主创新能力的重要保障。一个地区的自主创新能力越强，越能淘汰高投入、高消耗的落后产能，越能对循环经济的发展提供技术支撑。

教育支出占财政支出比重（%）：是指教育支出在财政总支出中所占的比重。教育事物支出包括教育行政管理、学前教育、小学教育、初中教育、普通高中教育、普通高等教育、初等职业教育、中专教育、技校教育、职业高中教育、高等职业教育、广播电视教育、留学生教育、特殊教育、干部继续教育、教育机关服务等。教育支出占财政支出比重越大，说明政府对教育和人才培养的重视程度和投入程度越高。

每十万人口中高等学校在校学生数（人/十万人）：是指一个地区每十万人口中高等学校平均在校学生数。该指标能较好地反映一个地区高等教育的发展水平，指标数值越大，说明该地区高等教育的发展水平越高，对循环经济的发展提

供较好的人才支撑基础。

人均文化体育支出（元/人）：是指文化体育支出在财政总支出中所占的比重。它是衡量文化体育的投入强度，体现对个人身心健康的关注，在很大程度上能够反映社会发展进步。人均文化体育支出越大，说明社会系统发展越完善。

单位 GDP 综合能耗（吨标准煤/万元）：是指一个地区在报告期内创造单位地区生产总值所耗费的综合能源消费量。它是反映能源消费水平和节能降耗状况的一个主要指标，能很好说明一个地区经济活动对能源的利用程度。

单位 GDP 电耗（千瓦时/万元）：是指一个地区在报告期内创造单位地区生产总值所耗费的电力。它是反映电力消费水平和节能降耗状况的一个主要指标，能很好说明一个地区经济活动对电力的利用程度。

单位 GDP 水耗（立方米/万元）：是指一个地区在报告期内创造单位地区生产总值的用水量。它是反映水资源消费水平和节能降耗状况的一个主要指标，能很好说明一个地区经济活动对水资源的利用程度。

环境治理投资占 GDP 比重（%）：是指环境污染治理投资在地区生产总值中所占的比重。环境污染治理投资包括城镇环境基础设施建设投资、工业污染源治理投资和当年完成环保验收项目环保投资。环境治理投资占 GDP 比重越大，说明该地区对环境保护的重视程度和投入程度越高。

单位 GDP 废水排放量（吨/万元）：是指一个地区在报告期内创造单位地区生产总值需要排放的废水总量。指标数值越小，说明经济活动产生的污染排放越少，越符合循环经济的“减量化”原则。

单位 GDP 化学需氧量排放量（千克/万元）：是指一个地区在报告期内创造单位地区生产总值需要排放的化学需氧量 COD 总量。指标数值越小，说明经济活动产生的污染排放越少，越符合循环经济的“减量化”原则。

单位 GDP 氨氮排放量（千克/万元）：是指一个地区在报告期内创造单位地区生产总值需要排放的氨氮总量。指标数值越小，说明经济活动产生的污染排放越少，越符合循环经济的“减量化”原则。

单位 GDP 二氧化硫排放量（千克/万元）：是指一个地区在报告期内创造单位地区生产总值需要排放的二氧化硫总量。指标数值越小，说明经济活动产生的污染排放越少，越符合循环经济的“减量化”原则。

单位 GDP 氮氧化物排放量（千克/万元）：是指一个地区在报告期内创造

单位地区生产总值需要排放的氮氧化物总量。指标数值越小，说明经济活动产生的污染排放越少，越符合循环经济的“减量化”原则。

单位 GDP 工业固废产生量（吨/万元）：是指一个地区在报告期内创造单位地区生产总值需要产生的工业固体废物总量。指标数值越小，说明经济活动产生的污染排放越少，越符合循环经济的“减量化”原则。

农村沼气每人拥有量（立方米/人）：是指平均每个农村居民拥有的沼气量。沼气作为一种极具应用前景的可再生能源，其开发利用既能解决农村能源供应紧张局势，又不对环境产生负面影响。指标数值越高，说明农村可再生能源利用率越高，越符合循环经济的“再利用”原则。

城市工业用水重复利用率（%）：是指城市工业用水中重复利用的水量在总用水量中所占的比重。提高工业用水重复利用率，是节约用水、减少污染，改善生态环境、解决城市缺水的有效途径之一，能产生巨大的经济、社会和生态效益。指标数值越大，越符合循环经济的“再利用”原则。

城市污水日处理能力（万立方米/日）：是指城市每昼夜处理污水总量的能力。城市污水处理一方面为人们创造舒适干净的生活环境，为生产解决后续之忧；另一方面对污水处理技术升级，通过污水再生利用使得水资源在经济发展中的价值得到更大发挥。指标数值越大，越符合循环经济的“再利用”原则。

工业固废综合利用率（%）：是指工业固体废物综合利用量占工业固体废物产生量比重。工业固废数量庞大，种类繁多，成分复杂，对环境产生巨大的负担，工业固废综合利用是解决其环境危害的有效途径之一，能产生巨大的经济、社会和生态效益。指标数值越大，越符合循环经济的“再利用”原则。

城市生活污水集中处理率（%）：是指经过城市污水处理厂二级或二级以上处理且达到排放标准的城市生活污水量与城市生活污水排放总量的比值。城市污水具有排放量大、地点集中、污染物种类复杂等特点，集中处理能大大解决水污染问题。指标数值越大，说明城市对污水集中处理的重视程度和投入程度越高。

生活垃圾无害化处理率（%）：是指无害化处理的城市生活垃圾数量占城市生活垃圾产生总量的比重。生活垃圾无害化处理能降低垃圾及其衍生物对环境的影响，减少污染物排放，做到资源回收利用。指标数值越大，说明城市对生活垃圾无害化处理的重视程度和投入程度越高。

（三）指标计算

对于上述构建的指标体系，部分指标数据可以直接获得，有一些需要通过简单的数学运算间接计算得到：

地区生产总值增速，可以直接查询地区《国民经济和社会发展统计公报》获得；

人均地区生产总值=地区生产总值/常住人口数；

人均财政收入=财政总收入/常住人口数；

人均消费品零售总额=社会消费品零售总额/常住人口数；

第三产业增加值占 GDP 比重=第三产业增加值/地区生产总值；

社会固定资产投资占 GDP 比重=社会固定资产投资额/地区生产总值；

城镇化水平=城镇人口数/城乡总人口数；

人均公园绿地面积=城市公园绿地面积/城市非农业人口数；

建成区绿化覆盖率=建成区绿化覆盖面积/建成区面积；

人均城市道路面积=城市道路面积/城市非农业人口数；

每千人的私人汽车拥有量=私人汽车拥有量/常住人口数；

城镇居民人均可支配收入，可以直接查询地区统计年鉴获得；

社会保障支出占财政支出比重=社会保障支出/财政总支出；

医疗卫生支出占财政支出比重=医疗卫生支出/财政总支出；

每千人的公共汽车拥有量=公共汽车拥有量/常住人口数；

R&D 经费投入强度=全社会 R&D 经费支出/地区生产总值；

教育支出占财政支出比重=教育支出/财政总支出；

每十万人口中高等学校在校学生数，可以直接查询地区统计年鉴获得；

人均文化体育支出=文化体育支出/常住人口数；

单位 GDP 综合能耗=综合能源消费总量/地区生产总值；

单位 GDP 电耗=电力消费总量/地区生产总值；

单位 GDP 水耗=水资源消费总量/地区生产总值；

环境治理投资占 GDP 比重=环境治理投资费用/地区生产总值；

单位 GDP 废水排放量=废水排放总量/地区生产总值；

单位 GDP 化学需氧量排放量=化学需氧量 COD 排放总量/地区生产总值；

单位 GDP 氨氮排放量=氨氮排放总量/地区生产总值；

单位 GDP 二氧化硫排放量=二氧化硫排放总量/地区生产总值；

单位 GDP 氮氧化物排放量=氮氧化物排放总量/地区生产总值；

单位 GDP 工业固废产生量=工业固体废物产生量/地区生产总值；

农村沼气每人拥有量=沼气产生总量/农村人口数；

城市工业用水重复利用率=城市工业用水重复利用量/城市总用水量；

城市污水日处理能力=城市污水处理总量/城市污水处理天数；

工业固废综合利用率=工业固体废物综合利用量/工业固体废物产生总量；

城市生活污水集中处理率=城市生活污水集中处理量/城市生活污水排放总量；

生活垃圾无害化处理率=城市生活垃圾无害化处理量/城市生活垃圾产生总量；

在获得了循环经济发展水平综合评价的指标数据之后，就得到了一个多指标属性为分析对象的综合评价问题。

第四章　循环经济评价方法选择与改进

一、常用的评价方法比较分析

（一）熵值法

熵的概念最初是德国物理学家克劳修斯提出的，它揭示了热传递的不可逆性：热能总是自发地从高温热源向低温热源流动，而不能反向流动。它表示任何一种能量在空间中分布的均匀程度，能量分布得越均匀，熵就越大。熵值法是根据各个方案之间指标数据的差异程度来确定权重的方法。熵原本是一个热力学概念，最早由香农引入信息论，而如今已在工程技术、社会经济等领域得到十分广泛的应用。根据信息论基本原理，信息熵是信息无序度的度量，信息则是系统有序程度的度量。一个系统的有序程度越高，则信息熵越大，其信息的效用值越小。所以，可以根据各指标效用值的差异程度，利用信息熵这个工具，计算出各指标的权重，为多指标综合评价提供基础。熵值法正是利用评价指标的固有信息来判别指标的效用值，从而在一定程度上避免了主观因素带来的偏差，可以客观准确地获得循环经济评价指标体系中各指标的权重。

（二）数据包络分析方法

数据包络分析法是在“相对效率评价”概念基础上发展起来的一种系统分析评价方法，进行样本的“相对优劣性”的评价。它主要采用数学规划方法，利用观察到的有效样本数据，对决策单元进行生产有效性评价。它具有特定的输入和输出，在将输入转化为输出的过程中，努力实现系统的可持续发展目标。对于循环经济整体系统而言，可持续发展的能力强，意味着系统用较少的资源消耗和较少的环境代价获得较大的经济、社会和资源环境效益，用数据包络分析的术语来表达即：把资源、环境作为输入，把经济和社会发展作为输出，其“相对有效性”即可用来衡量循环经济的可持续发展能力。

利用数据包络分析评价循环经济的技术有效性和规模有效性。在测定决策单元的相对有效性时，对每个决策单元进行优化，效率值为 1 的单元被称为相对有效单元，其同时满足其技术有效和规模有效，其对资源的配置能力和使用效率都是有效率的。对于非有效单元，利用“投影原理”指出指标的调整方向，还能给出调整量，并进行纵向的时间比较和横向的区域比较。运用其基本功能评价可持续发展能力，同时在评价基础上对循环经济系统的可持续发展能力建设、系统由非可持续向可持续发展以及对系统的预测、决策、协调和控制提供依据。

（三）神经网络分析方法

神经网络是由大量的简单单元通过广泛的连接而成的复杂网络，神经网络分析是指在分析复杂系统时，从底层单元开始分析并逐步向上延展，最终形成对整个系统的分析。它借鉴了现代神经科学的研究成果，并在此基础上延伸而来。神经网络分析通过模拟生物神经系统的功能及结构的若干基本特征，利用大量非线性并行处理关系来模拟众多的人脑神经元，对输入进行处理。它在信号处理、模式识别、智能控制等领域中得到了成功的应用，并逐步被引入到系统综合评价中。

神经网络评价的基本思想是：首先赋予网络起点初始权值，对每一个学习样本在网络中经过两次传递计算，一次向上传播计算，从输入层开始，传递各层并经处理后产生一个输出，并得到一个输出与目标输出之差的误差值；另一次向下传播计算，从输出层到输入层，利用误差值对权值进行逐层修改。对于循环经济发展水平综合评价而言，可将任意指标作为神经网络的起点，通过构建的网络体系，进行传输处理和验证，最终得到总体系统的评价结果。

（四）模糊综合评价法

模糊综合评价就是以模糊数学为基础，应用模糊关系合成的原理，将一些边界不清、不易定量的因素定量化，进行综合评价的一种方法。模糊综合评价是建立在模糊集合基础上的一种评价方法，它的特点在于其评价方式与人们的正常思维模式很接近，用程度语言描述评价对象。在定性因素的评判过程中，许多模糊现象如循环经济发展的社会效果、积极影响等很难明确地划定界限，无法用通常的简单数字来表达，所以只能用模糊数学来处理。它的数学原理首先考虑到影响循环经济综合评价的值的确定是模糊的，也就是在确定了循环经济综合评价指标体系之后对各不能直接定量表示的指标不做定量处理，而是由评估专家对各因素指标标准进行模糊选择，然后统计出专家群体对评估因素指标体系的选择结果，再按照所建立的数学模型进行最后计算。模糊评价法的过程就是先从定性的模糊选择入手，然后通过模糊变换原理进行运算取得结果。

（五）主成分分析法

循环经济评价指标体系中各指标之间的关系复杂、密切，使得指标之间存在很大程度的相关性，反映的信息有重叠；而且由于指标较多增加了分析问题的复杂性，因而需要对指标体系进行筛选、简化，找出其主要的影响因子。

Hotelling于1933年首先提出的主成分分析法是一种广泛应用的多元统计分析方法，善于处理繁杂的多指标问题，易于分析潜在影响因素，比较指标的重要程度，且主成分分析法是从循环经济评价指标的实际表现值出发，依靠指标的数值进行数据分析，权重的确定受人为因素影响较小，对循化经济的评价具有较强的客观性和可信度。

主成分分析是利用降维的思想，把多个指标转化为几个综合指标，但只会损失原始指标的一小部分信息，从而不影响评价结果。这几个综合指标被称为所谓的主成分，它们之间相互独立，数目大大少于原始变量的数目，且每个主成分都是原始变量的线性组合，这样在面对复杂的多指标问题时就可以只考虑少数几个综合指标，使问题得到简化，同时不影响评价结果，提高了分析问题的速度和效率，是诸多领域综合评价中一种简单易行的有效方法。

二、循环经济评价方法改进

（一）评价方法改进的必要性分析

以上各种方法都有其各自的优势和劣势状态，如熵值法、神经网络分析法作为典型的客观赋权法，虽利用较完善的数学理论与方法，且赋值的原始信息来源于客观环境，但忽视了决策者的主观信息；数据包络分析法在处理具有相同性质的部门（决策单元）进行多输入、多输出的比较分析方面存在很大的优势，但存在只有同类可比、对异常值相当敏感、往往只具有宏观意义等不足；模糊综合评价法在确定指标隶属度函数过程中不可避免的将已“白化”的信息模糊化，从而形成评价误差；传统主成分分析法虽可以有效简化指标体系，但其只能分析静态的截面数据，不能用来分析具有时间序列特征的动态面板数据。

因此，为避免已有评价方法的缺陷，提高评价模型的科学性与便利性，获得全面、科学、准确的评价结果，需要根据具体的评价对象、环境和目标等选用合适的评价方法，同时有必要对选用的方法进行一定程度的改进。

（二）主成分分析法的改进——全局主成分分析法

循环经济评价指标体系是一个涵盖经济系统、社会系统和资源环境系统三大系统，由目标层—系统层—准则层—指标层四大层次构成的复杂大系统，指标数量多、指标间关系复杂的问题突出，为了客观准确得到循环经济发展水平的综合评价结果，这里选用主成分分析法。同时考虑到传统主成分分析法不能分析具有时间序列特征的动态面板数据，仅能将面板数据按照不同时刻分成若干截面数

据进行分析的不足，这里对其进行一定程度的改进——全局主成分分析法能有效解决上述问题。

全局主成分分析法是将主成分分析原理应用于基于时间序列数据表，通过把不同时刻数据统一在相同的主平面，然后通过线性变化提取全局主成分，因此不同时刻的主成分的构成是相同的，经过主成分得到的主平面也是相同的，从而能够对不同时刻的相同样本结果进行对比分析，进而反映出样本的动态变化特征。

（三）评价模型的构建

设存在一张由T张具有同名的样本点和指标变量的截面数据表依据时间顺序排列而成的时序立体数据表，记为$K=\left\{X^t \in R^{n\times p},\ t=1,2,\cdots,T\right\}$，用$e_1,\ e_2,\cdots,\ e_n$和$x_1,x_2,\cdots x_p$分别表示时序立体数据表中$n$个同名样本和$p$个同名指标变量，即时序立体数据表中的每张截面数据表x^t均以$e_1,\ e_2,\cdots,\ e_n$为样本点，以$x_1,x_2,\cdots x_p$为变量指标。

在t时刻截面数据表x^t中，样本点$e_1,\ e_2,\cdots,\ e_n$的取值分别为$e_1^t,e_2^t,\cdots,e_n^t$，则t时刻的样本群点为$N_i^t=\left\{e_i^t,\ i=1,2,\cdots,n\right\}$，全局样本群点为$N_i=\cup_{i=1}^{T}N_i^t$。

同理，用以上方式对变量$x_1,x_2,\cdots x_p$进行相同处理，则可得到变量集X全局数据表$X=(x_{ij}^t)_{T_{n\times p}}$，其重心的定义为：

$$g=\left(x_1,x_2,\cdots,x_p\right)=\sum_{t=1}^{t}\sum_{i=1}^{n}p_i^t e_i^t \tag{1}$$

式（1）中p_i^t是t时刻样本点e_i的权重，且满足以下要求：

$$\sum_{t=1}^{t}\sum_{i=1}^{n}p_i^t=1,\sum_{i=1}^{n}p_i^t=1/T \tag{2}$$

然后记全局变量为x_j，则有：

$$x_j=\left(x_{1j}^1,\cdots,x_{nj}^1,x_{1j}^2,\cdots,x_{nj}^2,\cdots,x_{1j}^T,\cdots,x_{nj}^T\right)\in R^{Tn} \tag{3}$$

根据一般数理统计原理可知，全局方差s_j^2和全局协方差S_{jk}表达式如下：

$$s_j^2=Var(x_j)=\sum_{i=1}^{t}\sum_{i=1}^{n}p_i^t(x_{ij}^t-x_j)^2 \tag{4}$$

$$S_{jk}=Cov(x_j,x_k)=\sum_{t=1}^{t}\sum_{i=1}^{t}p_i^t(x_{ij}^t-x_j)(x_{ij}^t-x_k) \tag{5}$$

由此构成全局协方差阵：

$$V=(S_{jk})_{p\times p}=\sum_{t=1}^{t}\sum_{i=1}^{n}p_i^t({}_i^t-g)({}_i^t-g)' \tag{6}$$

在定义全局分析相关概念后，接下来对全局主成分原理进行简要介绍。全局主成分分析的关键在于对于P维全局样本群点N_i通过坐标平移和旋转变化找到一个M维（$M<P$）全局主超平面$H+L$（先平移、再旋转变换），使得全局样本群点中的e_i^t在其上面的投影e_i^t与原始e_i^t综合差异达到最小，即满足最小二乘

法原则。在最小二乘法原则下得到的全局主超平面一定经过 N_i 的重心，且得到的最佳变换 L 的标准正交基 $u_1, u_2, \cdots, u_m$（即 $u_k M u_j = 1(j=k)/0(j \neq k)$），对应 VM 的前 m 个特征值 $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_m$，这里称 $u_1, u_2, \cdots, u_m$ 为全局主轴，是新变量的方向，V 和 M 分别是全局协方差矩阵和度量矩阵。然后得到以下表达式：

$$F_h(t,i) = (e_i^t - g)' M u_h \tag{7}$$

$$F_h = \left[F_h(1,1), \cdots, F_h(1,n), \cdots, F_h(T,1), \cdots, F_h(T,n)\right]' \in R^{Th} \tag{8}$$

称 F_h 为第 h 全局主成分，它是由样本群点 N_i 在第 h 主轴上的投影构成的。全局主成分分析在本质上就是对时序数据进行传统主成分分析，那么全局主成分分析就必然继承传统主成分分析的优良品质。

第一，全局主成分一定对应于数据变异最大的方向。根据传统主成分分析的原理可知，为了原始数据 $\{e_i^t, i=1,2,\cdots,n, t=1,2,\cdots,T\}$ 在全局主轴上的投影 e_i^t 与原始值综合差异最小，必然要求全局主轴按照数据方差变异大小的方向确定，然后根据原始数据在全局主轴上投影提取全局主成分，则第一个主成分（F_1）必然对应数据点分布方差变异最大的第一全局主轴，第二个主成分（F_2）必然对应数据点分布方差变异次大的第二全局主轴，其他综合变量方向的确定依此类推，即：

$$Var(F_1) \geq Var(F_2) \geq \cdots \geq Var(F_m) \tag{9}$$

第二，全局主成分是对原变量系统的最佳综合。在全局主成分中，如果找一个综合变量比较完美地取代全局数据表中的所有全局变量 $x_j, j=1,2,\cdots,p$，则这个综合变量一定是第一全局主成分，因为第一主成分包含最多的原始全局变量信息，即全局主成分 F_1 与全局变量 x_j 的相关度综合最大：

$$\sum_{j=1}^{p} r^2(F_1, x_j) \rightarrow \max \tag{10}$$

对 m 维主超平面，$F_h(h=1,2,\cdots,m)$ 与所有 x_j 的累积相关度可以达到综合最大，即：

$$\sum_{h=1}^{m} \sum_{j=1}^{p} r^2(F_h, x_j) \rightarrow \max \tag{11}$$

（四）模型评价步骤

运用全局主成分分析法综合评价循环经济发展水平，可分为以下几个步骤进行，这些步骤均可通过统计软件 SPSS 实现：①将时序立体数据表按照时间顺序展开建立全局数据表，这是全局主成分分析与传统主成分分析的关键区别之处；②对全局数据表中的数据进行预处理，以满足全局主成分分析要求，对全局数据

表中的逆向指标的数据实施正向化变换，在此基础上对所有指标数据进行标准化处理，得到标准化数据表；③计算标准化数据表的相关系数矩阵；④计算相关系数矩阵的特征根以及对应的特征向量，并且计算出特征根的单个贡献率与累积贡献率；⑤根据研究要求以及主成分的累积贡献率确定全局主成分的个数；⑥根据特征根与特征向量计算因子负荷矩阵，计算样本在每个全局主成分的得分；⑦根据所以主成分的累积贡献率对主成分的方差贡献率进行归一化处理，得到综合得分 F 与主成分 F_i 的表达式，然后计算出样本的综合得分。

第五章 循环经济综合评价的实证分析

一、数据获取和预处理

（一）数据获取

2005 年柴达木循环经济试验区成为国家首批 13 个循环经济产业试点园区，2008 年西宁（国家级）经济技术开发区成为国家第二批循环经济试点园区。长久以来青海省立足自身资源环境优势，在准确把握国际国内发展大势和科学判断青海经济社会发展阶段性特征的基础上，坚持把发展循环经济作为转变经济发展方式、实现可持续发展及提高地区经济竞争力的主攻方向，努力把青海建设成为国家循环经济发展先行区。目前规划政策体系基本形成，产业框架初步构建，产业链条不断延伸，园区示范带动作用明显，基础设施逐步完善，科技支撑显著增强，青海省循环经济发展已由探索起步推进到科学发展阶段。

为了探索更有效的循环经济发展途径，实现循环经济发展的新突破，有必要对循环经济发展的现状进行全面剖析，从而为循环经济的进一步发展指明方向。因此，当前对青海省循环经济发展水平进行综合评价是尤为必要的，一是可以准确了解当前青海省循环经济的发展水平以及未来的发展趋势，二是可以为政府规划政策和保障措施的制定提供理论和现实依据。这里从横向比较和纵向比较两个角度对青海省循环经济发展水平进行客观准确地评价。

横向比较：国家发改委、环境保护部、科学技术部等七部委共同组织开展了国家循环经济试点示范单位的验收工作，并于 2015 年公布了《通过验收的国家循环经济试点示范单位名单（第二批）》。其中，天津、辽宁、上海、江苏、安徽、山东、湖南、广东、重庆、四川、陕西、甘肃、青海这 13 个省市作为我国循环经济发展水平较高的地区，通过了循环经济试点地区的验收。通过这 13 个省市的循环经济发展水平的横向比较可以客观准确了解当前青海省循环经济在我国的发展状况。

纵向比较：通过 2010-2014 年上述 13 个省市循环经济发展的纵向时序动态变化比较，不仅可以了解青海省循环经济发展的变化趋势，而且可以比较不同省市循环经济发展的变化趋势，从发展趋势角度了解当前青海省循环经济在我国的发展状况。

按照构建的循环经济评价指标体系，查询《中国统计年鉴 2011-2015》、《中国环境统计年鉴 2011-2015》、《中国环境年鉴 2011-2015》、《中国城市统计年

鉴2011-2015》、《中国科技统计年鉴2011-2015》、《中国能源统计年鉴2011-2015》以及各省市统计年鉴（2011-2015）获取相关指标2010-2014年的原始数据。

（二）数据预处理

在数据分析之前，通常需要先将数据预处理，利用标准化的数据进行数据分析。数据标准化也称为统计数据的指数化。数据标准化处理主要包括数据正向化（同趋化）处理和无量纲化处理两个方面。

同趋化处理：构建的循环经济评价指标体系包括不同性质的指标，对于正向指标，具有这种指标属性的特点是要求其指标的取值越大越好；对于逆向指标，具有这种指标属性的特点是要求其指标的取值越小越好。数据同趋化处理主要解决不同性质指标问题，对不同性质指标直接加总不能正确反映不同作用力的综合结果，须先考虑改变逆向指标性质，使所有指标对综合评价的作用力同趋化。

正向指标有：地区生产总值增速X1、人均地区生产总值X2、人均财政收入X3、人均消费品零售总额X4、第三产业增加值占GDP比重X5、社会固定资产投资占GDP比重X6、城镇化水平X7、人均道路面积X8、建成区绿化覆盖率X9、人均城市道路面积X10、城镇居民人均可支配收入X12、社会保障支出占财政支出比重X13、医疗卫生支出占财政支出比重X14、每千人的公共汽车拥有量X15、R&D经费投入强度X16、教育支出占财政支出比重X17、每十万人口中高等学校在校学生数X18、人均文化体育支出X19、环境治理投资占GDP比重X23、农村沼气每人拥有量X30、城市工业用水重复利用率X31、城市污水日处理能力X32、工业固废综合利用率X33、城市生活污水集中处理率X34、生活垃圾无害化处理率X35。

逆向指标有：每千人的私人汽车拥有量X11、单位GDP综合能耗X20、单位GDP电耗X21、单位GDP水耗X22、单位GDP废水排放量X24、单位GDP化学需氧量排放量X25、单位GDP氨氮排放量X26、单位GDP二氧化硫排放量X27、单位GDP氮氧化物排放量X28、单位GDP工业固废产生量X29。

无量纲化处理：不同的指标往往具有不同的度量单位，因此不同的量纲之间就必然会存在差异，这种差异就会造成不同指标之间缺乏可比性。指标数据无量纲化处理也称为数据的规格化，是一种通过数学变换来消除原始变量量纲影响的方法，主要解决指标的可比性。

对于以上两种由于指标的性质不同或度量单位不同，其都会引起不同的指

标之间无法直接进行比较，因此，需要对各个评价指标的指标数据进行同趋化处理和无量纲化处理。常用的对指标数据进行标准化的方法有：极差变换法、线性比例变换法、向量归一化法、标准样本变换法等处理方法，它们各自具有各自的优点与缺点。这里选择极差变换法对指标数据进行处理。

设有n个评价指标$f_j(1\le j\le n)$，m个待评价对象$a_i(1\le i\le m)$，m个待评价对象的n个指标值构成的矩阵$X=(x_{ij})_{m\times n}$称为决策矩阵。在决策矩阵$X=(x_{ij})_{m\times n}$中，对于正向指标：

$1\le i\le m$ y $1\le i\le m$ y

（12）

对于逆向指标：

$1\le i\le m$ y $1\le i\le m$ y

（13）

矩阵$Y=(y_{ij})_{m\times n}$称为极差变换标准化矩阵。极差变换法的优点是无论决策矩阵$X=(x_{ij})_{m\times n}$中的指标值是正数还是负数，经过极差变换之后，标准化指标满足$0\le y_{ij}\le 1$，并且正、逆向指标均化为正向指标，最优值为 1，最劣值为 0。表 5-1 展示了 2014 年指标数据经过同趋化和无量纲化预处理得到的标准化矩阵。

表 5-1　标准化矩阵（2014 年）

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17
天津	0.824	1.000	0.807	0.746	0.483	0.419	0.847	0.245	0.347	0.780	0.000	0.359	0.091	0.058	0.931	0.770	0.708
辽宁	0.000	0.492	0.287	0.596	0.218	0.617	0.529	0.439	0.788	0.478	0.599	0.269	1.353	0.002	0.473	0.296	0.033
上海	0.235	0.900	1.000	1.000	1.000	0.000	1.000	0.000	0.644	0.022	0.793	1.000	0.255	0.000	1.000	1.000	0.283
江苏	0.569	0.704	0.398	0.683	0.395	0.394	0.491	0.724	1.000	0.871	0.384	0.464	0.000	0.333	0.397	0.632	0.690
安徽	0.667	0.101	0.064	0.099	0.000	0.804	0.156	0.602	0.881	0.548	0.997	0.112	0.580	1.000	0.028	0.418	0.485
山东	0.569	0.437	0.156	0.547	0.276	0.466	0.278	1.000	1.017	1.000	0.332	0.274	0.344	0.839	0.226	0.516	1.000
湖南	0.725	0.176	0.047	0.200	0.231	0.650	0.159	0.265	0.661	0.478	0.977	0.176	0.704	0.814	0.036	0.243	0.561
广东	0.392	0.470	0.302	0.579	0.463	0.134	0.549	0.918	0.898	0.551	0.477	0.383	0.049	0.835	0.526	0.576	0.914
重庆	1.000	0.272	0.235	0.314	0.388	0.614	0.374	0.990	0.831	0.000	0.911	0.124	1.000	0.556	0.300	0.263	0.294
四川	0.529	0.110	0.071	0.176	0.112	0.569	0.096	0.408	0.568	0.070	0.841	0.090	0.769	0.861	0.113	0.313	0.442
陕西	0.765	0.260	0.148	0.192	0.054	0.726	0.227	0.531	0.822	0.265	0.670	0.095	0.772	0.678	0.160	0.477	0.662
甘肃	0.608	0.000	0.000	0.000	0.293	0.910	0.000	0.561	0.000	0.033	1.000	0.000	0.939	0.711	0.000	0.164	0.469
青海	0.667	0.168	0.106	0.012	0.054	1.000	0.169	0.357	0.068	0.052	0.621	0.019	0.381	0.152	0.249	0.000	0.000

表 5-1 续　标准化矩阵（2014 年）

X18	X19	X20	X21	X22	X23	X24	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34	X35
1.000	0.421	0.937	1.000	1.000	0.820	1.000	0.909	1.000	0.930	0.919	0.995	0.046	0.984	0.125	1.000	0.864	0.912

0.559	0.197	0.749	0.928	0.788	0.311	0.543	0.268	0.533	0.649	0.631	0.827	0.019	0.984	0.411	0.000	0.794	0.775
0.695	0.508	0.974	0.978	0.816	0.379	0.517	1.000	0.919	1.000	1.000	1.000	0.000	0.893	0.413	0.970	0.850	1.000
0.535	0.259	0.983	0.906	0.531	0.559	0.536	0.836	0.848	0.922	0.898	0.984	0.107	0.774	0.871	0.959	0.535	0.949
0.335	0.035	0.892	0.910	0.285	1.000	0.037	0.269	0.214	0.794	0.477	0.907	0.026	0.886	0.319	0.804	0.864	0.987
0.392	0.025	0.863	0.929	0.871	0.584	0.612	0.546	0.747	0.754	0.730	0.955	0.304	0.944	0.494	0.941	1.000	1.000
0.307	0.000	0.900	0.986	0.332	0.211	0.246	0.203	0.000	0.802	0.866	0.967	0.467	0.215	0.284	0.423	0.577	0.992
0.371	0.081	1.000	0.905	0.690	0.000	0.000	0.665	0.636	0.963	0.948	1.000	0.054	0.950	1.000	0.790	0.897	0.636
0.587	0.004	0.872	0.968	0.745	0.453	0.407	0.610	0.509	0.620	0.771	0.975	0.632	0.000	0.123	0.789	0.911	0.979
0.334	0.102	0.799	0.925	0.580	0.348	0.227	0.265	0.238	0.739	0.864	0.921	1.000	0.669	0.271	0.097	0.568	0.877
0.794	0.274	0.847	0.935	0.780	0.720	0.666	0.578	0.583	0.525	0.452	0.923	0.151	0.928	0.135	0.412	0.903	0.888
0.326	0.156	0.488	0.588	0.000	1.025	0.482	0.000	0.033	0.000	0.000	0.846	0.403	1.000	0.070	0.207	0.468	0.000
0.000	1.000	0.000	0.000	0.386	0.528	0.439	0.200	0.351	0.226	0.060	0.000	0.064	0.273	0.000	0.306	0.000	0.634

二、评价过程与结果

（一）变量描述统计

将预处理后的（13×35）×5 全局样本标准化数据表导入多元统计分析软件 SPSS19.0，首先对样本数据进行 KMO 和 Bartlett 球形度检验，以查验样本数据是否适合进行全局主成分分析，检验结果（见表 5-2）显示，变量间偏相关性的 KMO 统计量数值为 0.778，球形度检验的结果显著性水平为 0.000，根据 Kaiser（1974）提出的 KMO 度量标准可知，该样本数据比较适合进行全局主成分分析。

表 5-2 KMO 和 Bartlett 球形度检验结果

KMO 值		0.778
Bartlett 球形度检验	卡方统计值	4351.134
	自由度	595
	显著性水平	0.000

（二）特征值选取及主成分确定

应用 SPSS19.0 进行主成分分析，对 35 个变量进行方差最大正交旋转，以特征值大于 1 和累积方差贡献率大于 85%为标准提取主成分。从表 5-3 可以看出，前 7 个成分的特征值分别为 15.857、5.521、2.724、2.481、1.845、1.260、1.147，且这 7 者的累积贡献率达到 88.101%，大于 85%，因此应提取前 7 个全局主成分作为新的综合变量，分别用 F_1、F_2、F_3、F_4、F_5、F_6、F_7表示，即通过对（13×35）×5 全局样本数据表进行全局主成分分析，构建了 7 个新的综合变量代替原始 35 个指标变量，减少了 28 个指标变量，降维幅度达 80%，降维效果比较好，浓缩

了原始指标数据的绝大部分信息。从碎石图（图 5-1）也可以得到相同的结论。

将 7 个全局主成分的特征值代入 $W_i = \lambda_i / \sum_{i=1}^{l} \lambda_i$ 进行归一化处理，从而得到 7 个全局主成分对综合得分的影响权重，分别为 0.514、0.179、0.088、0.080、0.060、0.041、0.037，最终得到循环经济发展水平的综合得分与各个主成分之间的关系表达式：

$$F = 0.514F_1 + 0.179F_2 + 0.088F_3 + 0.080F_4 + 0.060F_5 + 0.041F_6 + 0.037F_7 \quad (14)$$

表5-3　特征值、贡献率和累积贡献率

成份	初始特征值			提取平方和载入			旋转平方和载入		
	合计	方差 %	累积 %	合计	方差 %	累积 %	合计	方差 %	累积 %
1	15.857	45.304	45.304	15.857	45.304	45.304	11.776	33.646	33.646
2	5.521	15.774	61.079	5.521	15.774	61.079	5.633	16.094	49.740
3	2.724	7.784	68.863	2.724	7.784	68.863	3.248	9.279	59.019
4	2.481	7.089	75.952	2.481	7.089	75.952	3.231	9.231	68.250
5	1.845	5.271	81.224	1.845	5.271	81.224	2.638	7.537	75.787
6	1.260	3.599	84.823	1.260	3.599	84.823	2.636	7.531	83.318
7	1.147	3.278	88.101	1.147	3.278	88.101	1.674	4.783	88.101
8	.829	2.368	90.469						
9	.669	1.913	92.382						
10	.556	1.588	93.969						
11	.367	1.048	95.018						
12	.351	1.002	96.020						
13	.325	.927	96.947						
14	.223	.637	97.585						
15	.166	.475	98.060						
16	.117	.335	98.395						
17	.104	.297	98.693						
18	.094	.269	98.962						
19	.075	.214	99.176						
20	.064	.184	99.360						
21	.049	.140	99.500						

22	.038	.108	99.608						
23	.031	.090	99.698						
24	.029	.082	99.780						
25	.019	.054	99.834						
26	.015	.044	99.878						
27	.012	.035	99.913						
28	.008	.023	99.936						
29	.006	.018	99.953						
30	.005	.013	99.967						
31	.004	.012	99.978						
32	.003	.008	99.986						
33	.002	.007	99.993						
34	.002	.005	99.998						
35	.001	.002	100.000						

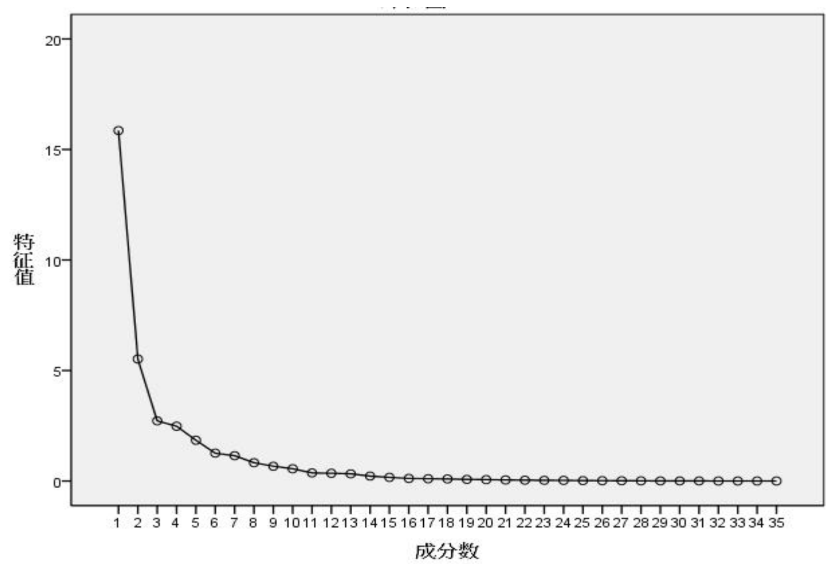

图 5-1　碎石图

（三）主成分及综合得分确定

根据全局主成分载荷矩阵（表 5-4），可以得到各主成分与原始各指标变量之间的关系。变量 X2、X3、X7、X15 等在主成分 F_1 上载荷较大；变量 X20、X21、X29 等在主成分 F_2 上载荷较大；变量 X13、X33 等在主成分 F_3 上载荷绝对

值较大；变量 X8、X9 等在主成分 F_4 上载荷较大；变量 X10、X24、X31 等在主成分 F_5 上载荷较大；变量 X1、X32 等在主成分 F_6 上载荷绝对值较大；变量 X23、X28 等在主成分 F_7 上载荷绝对值较大。主成分 F_1 、F_2 、F_3 与各指标变量的三维系数还可以参照图 5-2。

表 5-4 全局主成分载荷矩阵

变量	F_1	F_2	F_3	F_4	F_5	F_6	F_7
X1	-.285	-.038	.016	.142	-.060	-.849	-.108
X2	.905	.137	.193	.132	.259	.030	.112
X3	.971	.171	.054	-.055	.030	-.008	.072
X4	.859	.269	.142	.162	.196	.189	.152
X5	.745	.246	.219	-.239	-.114	.162	.144
X6	-.605	-.337	-.377	-.013	.097	-.363	-.295
X7	.955	.173	.071	.091	.061	.101	.055
X8	-.287	.233	.267	.663	.024	.103	-.352
X9	.055	.570	.111	.663	-.018	.358	-.026
X10	.018	.148	.480	.389	.612	.257	.061
X11	-.530	.084	-.329	-.327	-.623	.131	-.101
X12	.847	.267	.239	.003	-.054	.292	.118
X13	-.357	-.155	-.815	-.114	-.130	-.146	-.050
X14	-.796	.331	.301	-.228	-.032	-.016	.027
X15	.960	.025	-.005	-.013	.068	.109	.094
X16	.773	.447	.280	-.024	.228	.081	.062
X17	-.192	.403	.636	.076	.468	.100	-.064
X18	.677	.493	-.029	-.028	.327	-.338	-.039
X19	.635	-.579	-.077	-.265	.065	-.118	-.023
X20	.283	.844	.314	.168	.085	.155	.096
X21	.184	.919	.088	.201	.103	.022	.085
X22	.618	.307	-.044	.541	.305	-.132	.097
X23	-.116	-.058	.026	.004	.012	-.110	-.863
X24	.434	-.017	-.119	.039	.644	-.489	.005

X25	.770	.255	.381	.250	.100	.023	-.068
X26	.766	.128	.254	.373	.296	.055	-.077
X27	.481	.472	.352	.355	.029	.257	.310
X28	.478	.476	.235	.443	-.129	.136	.453
X29	.180	.877	.196	.041	.069	.014	.101
X30	-.534	.206	-.141	.088	-.321	-.397	.289
X31	.158	.252	.083	-.321	.749	.298	-.139
X32	.151	.234	.428	.283	.111	.727	.125
X33	.499	.284	.701	.210	-.037	.015	-.141
X34	.330	.703	.037	.400	.087	-.029	-.249
X35	.194	.250	.122	.731	-.039	-.260	.207

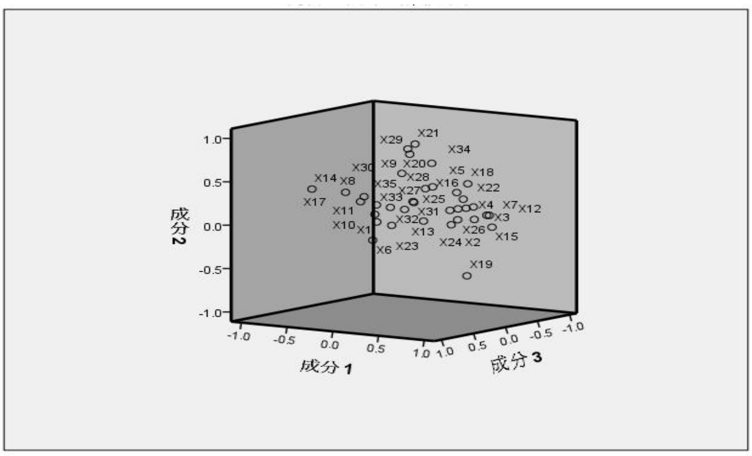

图 5-2　旋转空间中的成分图

应用 SPSS19.0 可以获得各主成分的得分，通过式（14），可以计算出 2010-2014 年各省市循环经济发展水平的综合得分，如表 5-5 所示。

表 5-5　2010-2014 年各省市循环经济发展水平的综合得分

	2010	2011	2012	2013	2014	得分变化	排名变化
天津	0.776	0.839	0.882	0.885	0.866	0.090	2→2
辽宁	0.058	0.078	0.139	0.150	0.130	0.072	6↑5
上海	1.241	1.196	1.233	1.259	1.177	-0.064	1→1
江苏	0.330	0.324	0.344	0.370	0.366	0.036	4↑3
安徽	-0.446	-0.458	-0.522	-0.399	-0.377	0.069	11↑9
山东	0.061	0.023	0.049	0.069	0.030	-0.031	5↓6

湖南	-0.426	-0.445	-0.412	-0.382	-0.398	0.028	10→10
广东	0.361	0.282	0.285	0.287	0.220	-0.141	3↓4
重庆	-0.107	-0.026	0.011	-0.004	0.004	0.111	7→7
四川	-0.402	-0.452	-0.419	-0.432	-0.402	0.000	9↓11
陕西	-0.217	-0.118	-0.089	-0.082	-0.077	0.140	8→8
甘肃	-0.795	-0.856	-0.786	-0.761	-0.767	0.028	13→13
青海	-0.743	-0.629	-0.625	-0.636	-0.629	0.114	12→12
均值	-0.024	-0.019	0.007	0.025	0.011	0.035	—

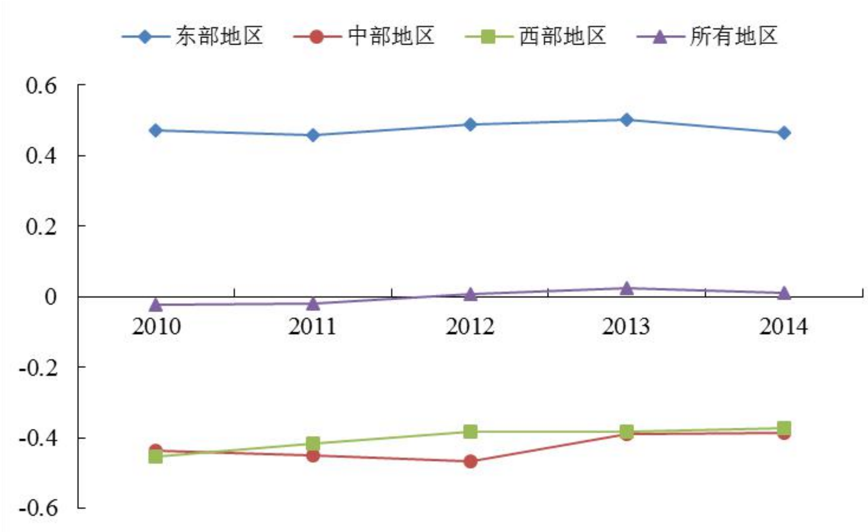

图 5-3　各地区循环经济发展水平综合得分的趋势

三、循环经济综合评价的实证结果分析

（一）总体发展状况

根据表 5-5 可知，从 2010 年到 2014 年，13 个省市循环经济发展水平综合得分的均值（所有地区循环经济发展水平的综合得分）经历了一个上升转下降的波峰态势，由 2010 年的-0.024 增至 2013 年的波峰值 0.025，上升幅度为 0.049；2013 年后，循环经济发展水平的综合得分处于缓慢下降的状态，由 2013 年的 0.025 降至 2014 年的 0.011，下降幅度为 0.013。总体而言，2010-2014 年循环经济发展水平的综合得分平稳波动，略有增长，上升幅度为 0.035，各省市循环经济呈现良好发展的态势。

从计算结果的区域分布情况来看，各地区的循环经济发展水平存在明显的

空间二元结构（见图 5-3）。东部地区循环经济发展水平的综合得分远高于中部和西部地区；西部地区循环经济发展水平的综合得分略高于中部地区，都明显低于所有地区的平均水平。从发展趋势来看，即从各地区循环经济发展水平综合得分曲线的陡峭变化情况可知，近年来东部地区循环经济发展水平的综合得分处于缓慢下降的状态，而中部和西部地区循环经济发展水平的综合得分处于持续上升的状态。总体而言，东部、中部和西部地区循环经济发展水平的差距呈现良性缩小的态势。

（二）各省市发展状况

从各省市循环经济发展水平综合得分的变化情况来看（见表 5-5），各省市循环经济发展水平的综合得分总体呈现稳步上升的趋势。从 2010 到 2014 年，13 个省市中有 9 个省市循环经济发展水平的综合得分处于增长的状态，分别为：天津、辽宁、江苏、安徽、湖南、重庆、陕西、甘肃和青海，其中增长较快的是陕西、青海省和重庆，增幅均超过 0.1；综合得分处于下降状态的省市为：上海、山东、和广东，其中，广东的下降幅度最大，为-0.141。可以看到，西部各省市循环经济发展水平的综合得分大体都处于上升状态，相比而言，西部省市循环经济的发展态势要好于东部和中部省市。

从各省市循环经济发展水平综合得分的排名情况来看（见表 5-5），2010 年，循环经济发展水平综合得分排名前列的省市有：上海、天津、广东、江苏、山东，这些省市都集中在东部地区；排名后列的省市有：湖南、安徽、青海、甘肃，这些省市多数集中在西部地区，循环经济发展水平在空间上存在明显的不均衡态势。到 2014 年，排名位次未发生变化的省市有：上海、天津、重庆、陕西、湖南、青海、甘肃；辽宁、江苏、安徽的排名有所上升，其中安徽排名上升幅度较大，由 2010 的第 11 位上升到 2014 年的第 9 位，其他省市均上升了 1 位；山东、广东、四川的排名呈现下降趋势，四川的下降幅度均较大，由第 9 位下降到第 11 位，其他省市均下降了 1 位。2014 年，排名前列的省市有：上海、天津、江苏、广东、辽宁、山东，主要是一些东部省市，而四川、青海、甘肃这些西部省市排名仍然靠后。2010-2014 年，循环经济发展的空间不均衡态势并没有得到有效缓解，地区间存在明显的空间二元结构。

应用 SPSS19.0 对各省市循环经济发展水平综合得分进行系统聚类分析，冰柱图（见图 5-4）提供了系统聚类分析的并类信息，包括整个聚类过程或者是选

定类数范围内的部分。当聚成 3 类时，天津、上海为第一类，这一类中各省市循环经济的发展水平均较高；辽宁、山东、重庆、陕西、江苏、广东为第二类，这一类中各省市循环经济的发展水平次之；安徽、湖南、四川、甘肃、青海为第三类，这一类中各省市循环经济的发展相对滞后，发展水平较低。

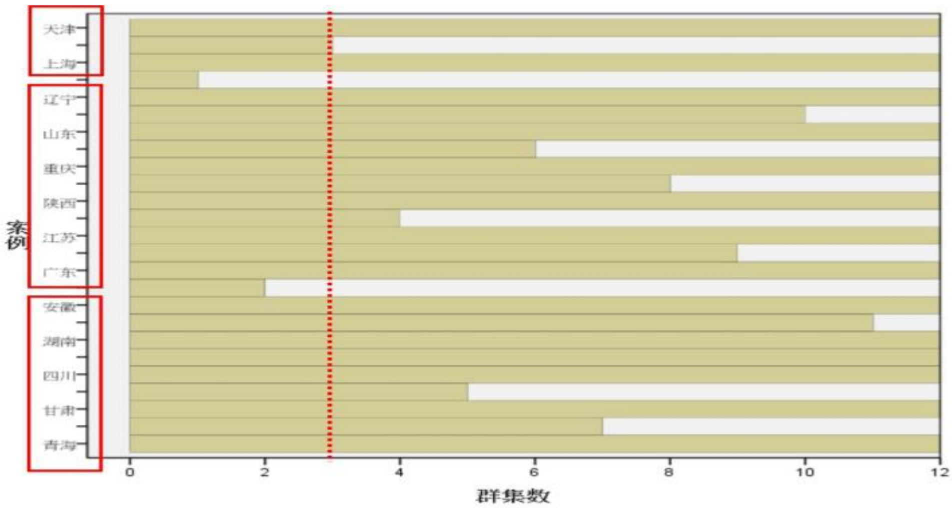

图 5-4　系统聚类的冰柱图

树形图（见图 5-5）以躺倒树的形式展现了聚类分析中的每一次类合并的情况。SPSS 自动将各类间的距离映射在 0～25 之间，并将聚类过程近似地表示在图上。首先合并成一类的是湖南、四川、安徽，其次是甘肃、青海，再次是江苏、广东，然后是辽宁、山东、重庆和陕西。以此类推，直到所有观测个案都合并成一类，此时类间的距离已经变得非常大了。冰柱图和树形图的结果是吻合的，二者反映的类合并情况是一样的。

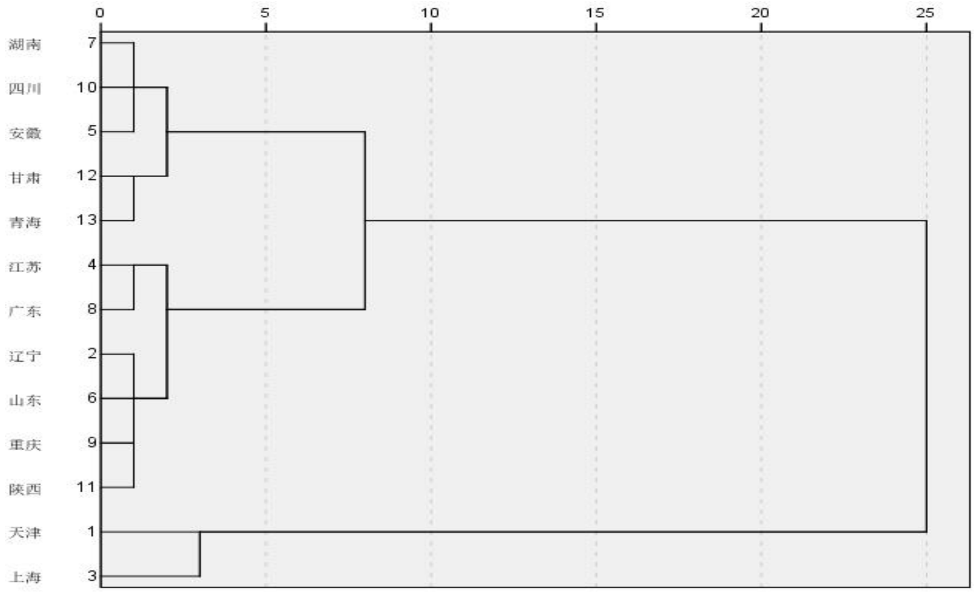

图 5-5　系统聚类的树形图

（三）青海省发展状况

1、横向比较

从横向省市间比较（见图 5-6）来看，从 2010 到 2014 年，青海省循环经济发展水平综合得分的排名在 13 个省市中排名末列，且长期以来这种状况并没有得到改善，青海省循环经济的发展水平与东部省市差距明显。东部省市近年来面临着资源约束趋紧、环境污染严重、生态系统退化等一系列问题，为了形成节约资源和保护环境的空间格局、产业结构、生产方式、生活方式，打造资源节约型和环境友好型社会，各省市坚持把发展循环经济作为转变经济发展方式的主要任务，作为我国先发地区，东部省市集聚了丰富的资金、人才、科技等资源和发展经验，经济社会发展的体量和质量也远高于中部和西部省市，近年来循环经济的发展取得了不错的成绩。青海拥有丰富的盐湖、石油天然气、有色金属等矿产资源和水、光、风能资源，可燃冰、油页岩等也被陆续发现，这些资源具有发展循环经济的独特优势。自“十一五”以来，青海省委、省政府立足省情发挥特色优势，发展循环经济成为转变经济发展方式的主攻方向。紧紧围绕建设国家循环经济发展先行区的总体要求，坚持以提高经济发展质量和效益为中心，将循环经济作为破解产业结构性矛盾的主要途径，着力推进产业集聚发展，切实形成区域大循环、产业中循环和企业小循环的循环经济产业发展格局。然而作为我国后发地区，青

海省经济社会发展的体量和质量远低于东部省市，受制于资金、人才、科技等资源的不足，同时由于其相对复杂的地理区位特点，青海省市场主体竞争力较弱，企业自主创新能力弱，产业层次低，传统产业面临产能过剩，新兴产业尚在起步阶段，缺少支撑和拉动作用明显的大企业、大项目，近年来循环经济的发展速度相对缓慢。从系统聚类的冰柱图（见图 5-4）也可以看到，青海省处于第三类，相比其他省市，青海省循环经济的发展水平存在明显的滞后。

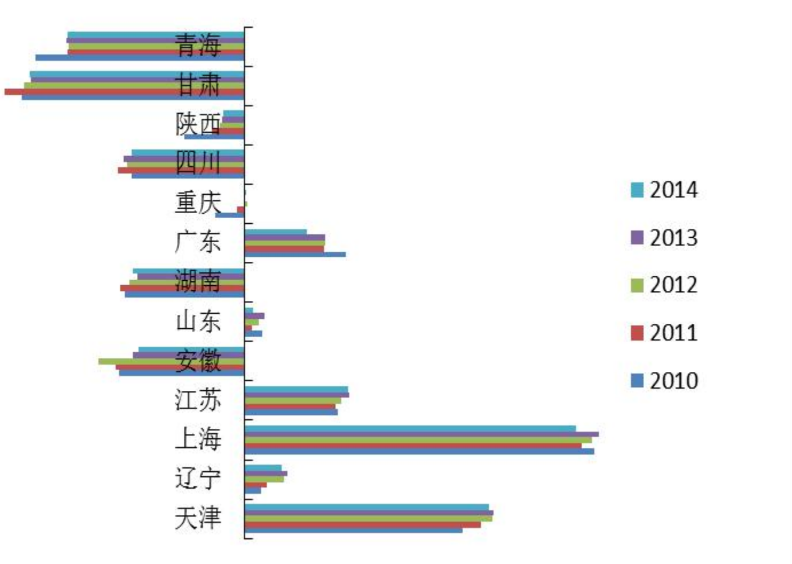

图 5-6　青海省循环经济发展水平横向比较图

2、纵向比较

从纵向时序动态变化（见图 5-7）来看，青海省循环经济发展水平的综合得分波动平稳，2010-2011 年增长幅度较大，达到 0.114， 2012 年综合得分达到最优值，2012 年后略有下降。总体上青海省循环经济的发展处于持续向好的态势，但也必须清楚的看到，青海省循环经济的发展水平与各省市平均水平相比差距明显。从 2010 到 2014 年，青海省循环经济发展水平的综合得分增长幅度在 13 个省市排名第 2 位，可见青海省循环经济的发展势头和发展潜力巨大，这与青海省政府重视循环经济的发展，建设国家循环经济发展先行区的目标与建设资源节约型、环境友好型社会的工作方针是分不开的。

近年来青海省政府加强节能降耗、节能减排等工作力度，淘汰过剩产能，转变粗放型经济增长模式，使单位生产总值能耗逐年下降，资源利用率明显提高，主要污染物排放得到明显控制，节能降耗、节能减排工作效果显著。从 2010 年到 2014 年，单位 GDP 综合能耗由 1.91 吨标准煤/万元降低到 1.73 吨标准煤/万元，单位 GDP 化学需氧量 COD 排放量由 6.15 千克/万元下降到 4.56 千克/万元，单

位 GDP 氨氮排放量由 0.61 千克/万元下降到 0.43 千克/万元，单位 GDP 二氧化硫排放量由 10.59 千克/万元下降到 6.70 千克/万元，单位 GDP 氮氧化物排放量由 9.19 千克/万元下降到 5.84 千克/万元。同时，青海省政府对废弃物的资源化和再利用更加重视，2010-2014 年，城市工业用水重复利用率由 44.62%上升到 48.2%，工业固废综合利用率由 42.2%上升到 56.3%。另外，青海省政府大力抓好主要园区的重点企业的循环经济试点工作，循环经济试点工作全面展开，农业、工业、服务业循环经济发展齐头并进，循环经济全面进步；积极推进循环经济政策法规建设，为青 障。

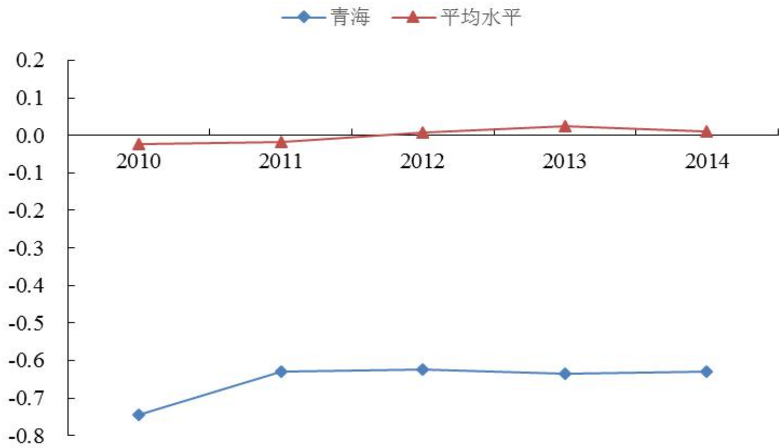

图 5-7 青海省循环经济发展水平纵向比较图

“十二五”期间，青海省的产业结构不断优化，10 大特色优势产业地位更加凸显，循环经济产业链初步形成，新能源、新材料、生物制品等新兴产业和特色产业发展迅猛。“十三五”时期是青海省循环经济承前启后、攻坚克难的关键时期，必须把握当今科技和产业变革方向，以创新为动力，加快推进结构调整，促进产业转型升级，全面提高质量的效益。按照《青海省建设国家循环经济发展先行区行动方案》，到 2020 年，产业布局科学合理，资源综合利用和产出率显著提高，循环经济规模不断扩大，成为发展主导模式，逐步构建完成循环型工业体系、循环型农业体系、循环型服务业体系和循环型社会，建成国家循环经济发展先行区。

第六章　青海省循环经济发展中存在的主要问题

实证结果表明：近年来，青海省的循环经济实践取得了显著成效，2010-2014年青海的循环经济发展水平得到了较大提升，综合得分增长幅度在13个省市排名第2位。但必须看到，青海省循环经济发展相对滞后（尤其和东部地区相比存在较大差距）的地位并没有得到有效改善。青海循环经济发展还面临诸多难题。根据园区、企业调研实际情况，课题组了解制约循环经济实际操作层面的园区和企业发展的一些主要问题，因此下文主要从社会、园区和企业三个层面探讨青海省循环经济发展中存在的主要问题。

一、社会层面

（一）产业结构不合理，资源环境压力过大

2014年青海省第三产业增加值占GDP的比重为37%，第三产业的比重相对较低，第一、二产业所占比重偏大。高耗能、高投入、高污染的重化工企业比重偏高，这种重型化的产业结构建立在大量耗用生态资源、环境资源和资本资源的基础上，造成资源环境承载压力过大。另外，产业布局不合理现象突出，地区产业结构趋同现象明显，造成严重的资源紧张和生产能力过剩，影响了生产要素资源的有效配置，制约了循环经济的发展。

（二）配套基础设施不健全，制约了循环经济的发展

在循环经济发展初期，配套基础设施没有跟上循环经济发展的步伐。第一，没有形成完善的再生资源回收交易体系，可再生资源废弃物市场和区域性废弃物处理中心没有形成规模，重点区域性再生资源集散市场及跨区域再生资源回收网络尚未建立；第二，污水、垃圾处理中心没有形成规模，垃圾处理技术有限，处理能力较低，城市生活污水处理厂、配套污水管网设置不足。

（三）经济发展滞后，影响了循环经济水平的提升

2014年青海省人均地区生产总值为39671元，在13个省市中排名末列。从经济发展水平来看，青海省作为西部后发地区，与中东部等先发地区存在较为明显的发展差距。先发地区凭借得天独厚的区位、资源、资金、技术和人才等优势，循环经济发展的速度较快。而青海由于经济发展程度和产业结构的因素，加上先天性的资源禀赋和生态环境基础，对资金、技术和人才等的集聚效应不足，循环

经济关键技术和关键人才欠缺，在很大程度上影响了循环经济发展水平的提升。

二、园区层面

（一）园区公共基础设施建设缺乏统一规划和部署

园区循环经济的发展，离不开完善的公共基础设施建设和统一的规划和部署。在园区调研过程中，发现青海省大多数园区资金紧张，园区环保基础设施尤其是工业污水及工业固体废弃物处置系统建设相对滞后的情况较为普遍。园区污染物排放、循环利用和改善环境质量的环保公共基础设施的超前或同步建设不足，这既增加了入园企业的环保设施建设和运营成本，又不利于园区建设的集聚及集约效应的有效发挥。

（二）园区产业链有待进一步延伸

在园区调研过程中，发现园区的发展规划不够科学与严谨，同时存在园区规划与实际操作有较大差异的问题，主管部门对入园的企业没有进行有效的筛选，未充分考虑入园企业产业的关联度，资源、信息沟通交流机制尚不健全，使园区企业产业链短、布局分散、废弃物在质和量上存在差异，未能有效促进整个经济结构的“循环”。园区企业间未形成紧密联系、共享共生的生态工业产业链，集约化程度和协调能力较弱，直接影响资源的利用率以及废弃物的资源化处理程度。

（三）园区管理和发展滞后

园区作为政府的派出机构，本应负责对辖区进行统一领导和管理，但调研发现，在实际工作中，园区管委会下设机构并没有审批操作权力和财政资金调用权力，使入园企业面临诸多问题。这种管理组织上的缺陷导致园区的运作存在不少问题。另外，园区缺乏有效的信息支撑体系，目前大多数园区尚未建立综合信息服务平台，不能及时地提供知识信息发布、信息查询和方案解决等服务。不建立一个政府主导、企业主办、行业推动、多方参与的循环经济信息服务平台，就无法使园区内循环经济产业链各环节实现有效衔接，也无法使园区与产品市场、资本市场、人才市场等建立密切的联系。

（四）园区服务支撑体系不完善

服务支撑体系不完善的问题是调研园区普遍存在的问题，首先，目前大多数园区都未能与大学和科研机构建立经常性的、有针对性的、制度性的联系，科研机构寻找项目及实现成果产业化不顺利。其次，缺少中介服务组织，企业要实现可持续发展就必须不断地进行技术、管理、制度、组织等一系列的创新，并且

使各种创新得以互动和网络化，这就需要中介服务组织充当企业和市场的桥梁。最后，要素市场和商品市场不发达，园区的人才市场、资金市场、技术市场等不发达，阻碍了各要素的合理有序流动。

三、企业层面

（一）对循环经济的认识存在误区

在企业调研过程中，发现目前很多企业对循环经济的内涵以及在现阶段发展循环经济的重要性和紧迫性缺乏系统的认识，仅仅从物质回收利用角度阐述循环经济，忽视了循环经济在物质消耗和污染排放上的源头预防和全过程控制的意义。另外，企业主体受既得利益的影响，往往追求经济效益的最大化。在没有外部约束的情况下，生态效益对于企业而言只是一个外部效益，企业一般会倾向于采用大量耗费廉价的自然资源和劳动力的粗放发展模式，忽视降低能源消耗的循环经济发展模式。对于众多企业而言，清洁生产还只是新概念，把清洁生产与过去的末端治理混同起来，认为清洁生产带来的生态环境效益是归社会所得，企业自身难以从中获得经济效益，再加上环境管理执法不严，致使企业发展循环经济的积极性并不高。

（二）缺乏有效的组织管理

企业部门维护环境质量的责权不明确，第一，在市场经济中，企业主要目标是追求利润的最大化，缺乏全局观念，虽然很多企业内部设立了相应的环保部门，但环保部门并不能起到核心作用，同时由于工作繁琐、涉及面广，造成工作协调难度大，维护环境质量的效果差。第二，企业的资金有限，处于应付心态而设置维护环境质量的部门难以发挥作用，无法实现发展循环经济的规模效应。企业由于缺乏社会环境责任感，在产品的设计、制造、包装、运输以及废弃物的处理，乃至产品的定价和售后服务等方面，都未充分考虑对环境的影响。

（三）缺乏大量非营利性的环保组织

在国外，非营利性的环保组织发挥了重要作用。作为环境领域的非政府组织，非营利性环保组织通过环境法的实施过程进行监测，帮助当地政府把可持续发展的理念贯穿到经济与社会发展的项目当中去，监督企业以更积极和自觉的态度保护环境。然而在企业调研过程中，发现当前这类环保组织在推进循环经济发展中的重要作用还没有得到充分重视，同时专门的环保组织在青海还很少，造成中间环节的缺失，并且多数环保组织在资金、人才方面还十分欠缺，限制了循环

经济的发展。

（四）缺乏社会环境责任感

绿色消费观念是发展循环经济的思想基础，绿色消费是实现循环经济发展“源头消减”的重要途径，绿色消费可以形成消费与生产的良性互动，因此建立绿色消费模式是发展循环经济的必要途径。作为绿色消费的载体，企业在绿色消费中发挥着举足轻重的作用。目前有些企业由于缺乏社会环境责任感，在产品的设计、制造、包装、运输以及废弃物的处理，乃至产品的定价和售后服务等方面，都未充分考虑对环境的影响，导致奢华消费、自然资源大量消耗等问题的出现。

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