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Discussion of the Chinese Development Strategies of Geothermal Resources Based on the Circular Economy

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ABSTRACT

In the context of energy crisis, Chinese government begins to vigorously advocate for the development of new energy sources in recent years including the geothermal energy. Though we have got a huge economic and social benefit, compared with other developed countries in the aspects of mining and using of geothermal resources, our using way and techniques are still in the low-level stage. To solve this problem, after analyzing the basic situation of geothermal resources in China, this article firstly introduces a new perspective, the Circular Economy Perspective. And then we analyze the roles which the government and enterprises should play in the process of creating a geothermal industry full of international competitiveness by Porter's "diamond model" and build a cycle model of whole life cycle of the products of geothermal resources on the basis of industry development. This article asserts a basic development strategy of Chinese geothermal resources in the coming 20-40 years as follows: clear the functions of government, cultivate the subjects of markets, create a circular economy-oriented geothermal resources industry which is full of international competitiveness in a planned market economy and form the new energy economy, the geothermal resources economy in particular.

1. THE CHARACTERISTICS AND UTILIZATION OF GEOTHERMAL RESOURCES IN CHINA

Geothermal resources are the thermal energies occurrence in the rocks and geothermal fluid and their concomitant useful components in the crust which can be economically exploited and utilized by humans under current situation of technology, economy and geological environment. According to the ***Renewable Energy Law of People's Republic of China*** published in 2006, geothermal energy, solar energy, wind energy, tidal energy, bioenergy and ocean energy are called as new energy in whole. Compared with solar energy, wind energy and tidal energy, geothermal energy is the most potential energy in these new energies. Thus, geothermal energy is an important renewable energy resource. It will be a clean and unexhausted energy if we adopt proper development mode.

Based on the modes of occurrence, geothermal resources can be classified into four types as follows (Han jianguang, Jiang zonglin, Tianyin et al, 2008): first one is hot water type, that is hot water or steam found in the deep-earth; second one is ground pressure type which are the high temperature and pressure fluid in the depth of some sedimentary basin; third one is hot dry rock type which hosted in hot dry rock which formed in special geological-tectonic conditions; the last one is magma type and it lies in the high temperature (700-1200^{o}C) melting magmatic bodies. According to the temperature, geothermal resources can be divided into high-temperature type (>150^{o}C), moderate-temperature type (90-150^{o}C) and low-temperature type (<90^{o}C). We should note that shallow geothermal energy in certain extent of depths under surface also belongs to geothermal resources.

In terms of global context, China is a country full of geothermal resources. High temperature geothermal fields, geothermal fields of Taiwan macao, Xizang yangbajin and Yunnan tengchong for example, respectively locate in circum-pacific geothermal belt or mediterranean himalayas geothermal belt. Besides there are high temperature geothermal fields at plate boundary caused by high heat flow areas of crust, there are also relatively high heat flow areas at interplates near plate boundary under certain geological conditions, such as Shandong peninsula, Liaoning peninsula, north China plain and southeast coast, where heat flow value is 1.7-2.0 heat flow unit. That is larger than continental average heat flow value (1.46 heat flow unit) (Zhengmin, 2007).

So far, there are more than 100 countries to exploit and use geothermal resources and this data increases by 12% per year. In 2010, it is expected that the amount of geothermal utilization will account for 30%-80% of the total value of world energy. There are more than 3200 geothermal areas found in China including 255 high-temperature geothermal areas used for power generation. According to statistics, heat energy in China generated by direct using geothermal resources is 12604.6GWh which is in the 1st place of the world and the equipment capacity is 3687Mt which is in the 3rd place by 2005 (Hanzaisheng, Zhengkeyan and Bindezhi, 2008). Although we gain a lot in using geothermal resources, there are some problems in exploiting and development resources: national investigation degree and evaluation degree are both low and the amount of this resource is not accurate; the level on exploitation and utilization is low and there are serious waste of resources; rough construction and over exploitation in some places result to potential crisis of resources destruction; there are imperfect national management system, legislative absence and unsoundness of market mechanism; the aspect of engineering thermal system exists gaps. Geothermal resources account for less than 0.5% of Chinese energy structure. Geothermal power generation in China only accounts for 0.35% of global geothermal power generation. In the circumstances of facing “energy crisis”, “scientific development view” and “circular economy” proposed by central government, using geothermal resources vigorously and effectively has been an important aspect of current energy application in China.

2. THE PROPOSAL OF CIRCULAR ECONOMY

The embryos of circular economy thought can be traced back to 1960s when the thought of environmental protection raised. In 1962, American ecologist Rachel Carson published her book ***silent spring***. This book

indicated the risks which biosphere and human had to face. The term “circular economy” was first proposed by American economist Kenneth E. Boulding. This concept means we should change from the traditional economy which relies on resource consumption to realize the linear growth to new economy which relies on the cycle of the ecological resource to realize the development. The objective of circular economy is to effectively and circularly use resources. Its characteristic is closed circuit cycle of materials and cascade utilization of energy. Circular economy is a kind of economic model which runs under the pattern of material cycle and energy flow in natural ecological system. It requires economic activities of human society to obey the ecology principles. It aims at realizing the sustainable development for society, economy and environment through decreasing the emission of pollutants by effective and cycle utilization of resources (Baidubaike, 2009).

From above definition, we can find that circular economy replaces the unidirectional linear type of industrial chain which pattern is resources-products-rubbishes by circular type which pattern is resources-products-renewable resources. In that way, we can achieve both harmonious development between nature and human being and coordinative development between resources consumption and economic growth well. Thus there are four principles of circular economy as follows:

(1) Reduce. That is to input natural resources from input terminal as less as possible. This principle requires us to develop the utilization efficiency of resources in order to decrease the consumption of resources.

(2) Reuse. It means to extend the using period of products as long as possible and to use products in various cases. So, we should pay attention to the cascade utilization of energy and the extension of industrial chain.

(3) Recycle. That is decreasing the emission of wastes as more as possible even zero emission. We can replace non-renewable resources by renewable resources and encourage the development of geothermal energy, the most potential energy, to put the production on natural ecological circulation.

To solve the problems of the increasing energy risk and deteriorate natural environment, Chinese government explicitly proposes that greatly develop circular economy and take it as an important way to adjust economic structure and economic layout for transformation of economic growth mode. In the 11^{th} five-year plan, Chinese government takes great development of circular economy and the construction of resource-saving and environment-friendly society as basic strategies.

From above analysis, we could draw a conclusion that greatly developing geothermal resources and raising the proportion which geothermal resources accounts for in Chinese energy consumption structure have been a necessary way to practice circular economy and realize sustainable development.

3. THE DISCUSSION OF DEVELOPMENT STRATEGY OF GEOTHERMAL RESOURCES

The proposal of circular economy both applies a valuable chance to exploit and use geothermal resources and raises a claim that the development of geothermal resources must obey the “3R” principle. Thus, in the next decades, a basic development strategy of Chinese geothermal resources is that under government supervision, we should apply market mechanic flexibly into recombinant kinds of geothermal resources links, such as exploration, evaluation, development, utilization, build geothermal resources industry and form the new energy economy, the geothermal resources economy in particular. In order to analyze how to recombinant industry chain of geothermal resources industry, this article introduces Porter's "diamond model" and builds a cycle model of whole life cycle of the products of geothermal resources on the basis of industry development.

In 1990, Michael E. Porter published a book named ***The Competitive Advantage of Nations***. In this book, he built a new analytic paradigm to national competitiveness. That is the diamond model. This model can answer the questions as follows: why are some countries successful but some countries fail in the international competition? Why can some industries gain long international competitiveness? He took his historical research on several hundred kinds of industries in 8 advanced countries (America, England, Sweden, Japan, Italy, German and Denmark) and 2 new industrialized countries (Korea and Singapore). In that research, he concluded that a country or an industry which wants to gain competitive advantage has to focus on four key elements. They are factor conditions, demand conditions, related and supporting industries and firm strategy, structure and rivalry. Besides that, there are two auxiliary factors: government and chance (Porter, M, 1990). The naming of diamond model comes from diamond relationship constituted by these four factors and two variables. This model is showed in figure 1.

FACTOR CONDITIONS: Porter divided factor condition into primary factor of production and advanced factor of production. In terms of geothermal industry, primary factor is basic proved reserve of Chinese geothermal resources. Although China has a history of using geothermal resources for more than 1000 years, we never took a national geothermal resources survey before. Thus, for the development of geothermal industry, it is a fundamental work to take a national general survey in order to clear the accurate reserve. Advanced factor of production includes talents who know the operation and management of geothermal resources, universities and institutes engaged in geothermal resources research. This advanced factor requires large quantity investment on the aspects of labor and capital in advance. We should publish some policies to elevate the research level of universities and institutes and encourage achievement transformation.

DEMAND CONDITIONS: demand market includes domestic market and international market. In terms of natural attributes of geothermal resources, they are not suitable for long-distance transportation. Thus, the main demand market for geothermal resources is domestic market, especially local market. Domestic demand includes structure, scale and growth of market. To geothermal industry, market structure can be mainly divided into geothermal power generation and direct application. On the aspect of market scale, the market of geothermal power generation grows slowly and installed capacity per year is only 28MWe. In the meanwhile, the market of direct application is 4300MWh (Hanzaisheng, Zhengkeyan and Bindezhi, 2008).

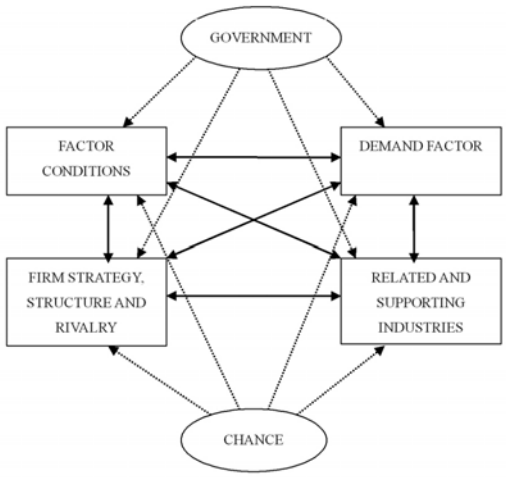

Figure 1: Porter's 'diamond' model - the determinants of national advantage

(This figure is cited from *The Competitiveness Advantage of Nations***)**

From above statistics, we can find that the market structure of geothermal industry is out of balance and the scale of geothermal power generation is small. So, in the coming 20-40 years, we should focus on the market of geothermal power generation including the development of generation technology of dry hot rock and enlarging the scale of high-temperature generation. In 2050, the installed capacity of the both means will rise to 500MW. At the same time, we should strengthen the research and extension of exploration and utilization technologies of geothermal resources. In 2050, the market scale of geothermal direct application will rise to 35000MWh (Hanzaisheng, Zhengkeyan and Bindezhi, 2008).

Besides that, we should actively exploit overseas markets and strengthen the research and development of technology and product which has independent intellectual property such as generation technology of spiral expansion power machine.

RELATED AND SUPPORTING INDUSTRIES: Porter claims that single firm or single industry is hard to keep competitive advantage and only forming effective industrial clusters and positive interaction between upstream industries and downstream industries can industrial competitive advantage be kept. This rule can be applied in geothermal industry. The major industry which has backward linkages with geothermal industry is resources exploration industry. The exploration of geothermal resources mainly adopts kinds of disciplines and means including geophysics, geochemistry, hydrogeology, airborne and spaceborne remote sensing. The application degree of these exploration technologies in geothermal industry is corresponding to the development level of its upstream industry, that is resources exploration industry. For certain firms, competitive upstream industry can provide advanced materials and technologies for them and these all are important parts of industrial competitiveness. The industries which have forward linkages with geothermal industry are real estate industry, tourism industry, agriculture, textile industry, paper industry, leather industry and so on. The development of geothermal industry can broaden the application range and level of these downstream industries and conversely the development of these downstream industries put forward the requirement for geothermal industry. This requirement helps geothermal industry to keep advantage of itself and realize healthy and sustainable development of itself. The industries which have lateral linkages with geothermal industry are coal industry, petroleum industry, natural gas industry, hydropower industry and so forth. They are all belonging to energy industry so as the geothermal industry. These energy industries commonly make demands for resources exploration industry and certain investigation means can apply to one or more kinds of energy industries. Take the selection of geothermal well location as an example. Because of having the results of oil and water production test, we can drill the wells where there are oil and gas exploratory wells. The data of the lithology, permeability and thickness of the aquifer, water temperature and hydrochemistry provided by oil exploratory wells play an important role in guiding the exploration and development of geothermal resources (Liao Zhongli, Zhang Yujie, Chen Wenbin et al, 2006). There is another example. In geothermal heating, we can adopt shaving design of cohesive heat-source. It gives low-temperature geothermal and waste heat a chance to be developed and used again by taking coal-fired, gas, off peak power and water-source heat pump as heat-source for peak adjusting (Wang Wanda, 2007). These related industries can form “promotion effect”. Under the circumstance of interworking technology accounting for high proportion and in the initial stage of industry life cycle, this effect will be significant. So, the development of geothermal industry is not isolated. We should develop geothermal industry in a high scope and promote geothermal industry development through building industrial clustersFIRM STRATEGY, STRUCTURE AND RIVALRY: this is an exercise about triangle relationship of corporate governance proposed by Porter. It includes some questions like how to found, organize and manage the firm, how to face the rivals. Firms, as the micro organization in industrial system, play an important role in the formation and development of industries. According to the development orientation of geothermal resources, we should found some professional geothermal firms which have definite property right, perfect governance mechanism, matured technological background and scientific management method to be responsible for the development and utilization of geothermal resources by the premise of regulating the market of exploration and mining

rights and carrying out paid exploitation. We should form an effective management mode of the development and utilization of geothermal resources through following the policy of developing under protection and protecting under development. We can encourage these professional firms to operate following the market law for the goal of paying attention both to social benefits and economic benefits and promoting local economic development. Free competition is the source of national competitiveness. The fierce domestic free competition can not only raise the competitive advantage of domestic enterprises but also force them to open up overseas markets. The free competition among geothermal firms can stimulate creative consciousness for themselves, integrate kinds of factor conditions and provide continuous forces for technical research of the development and utilization of geothermal resources. It helps to greatly develop certain key technologies, including application technology of shallow geothermal energy, dry hot rock technology, high-temperature power generation technology, geothermal water return irrigation technology and so on, which are related to the application prospect of geothermal energy.

CHANCE AND GOVERNMENT: On one side, in the 21st century, countries in the world have to face "energy crisis". The shortage of fossil fuels gradually becomes the foundation condition which constrains the development of all countries. Searching for alternative energy becomes a difficult task for the countries. On the other side, global warming led to the signing of ***United Nations Framework Convention on Climate Change***. The carbon emissions become a critical indicator. Non-sustainable traditional development mode made us reach an agreement that developing circular economy is the best way to go. Under this circumstance, geothermal resources, as the most potential energy of new energies, face a precious development opportunity. At the same time, we should know that these chances are not isolated and only linked with other factors of diamond model can they play a positive role.

Government is the last variable in diamond model. Porter claims that the government can create out competitive industries not by itself but by uniting with other variables of diamond model and guiding them. The role of government is providing good environment for the development of industries and firms. To be specific, government should carry out 3 major functions. The first one is administrative function. The governments should pay attention not to hospital operation but to hospital management. The GIS (Geothermal Information System) can be applied in the field of development and utilization of geothermal fields. The second one is legislation assurance. Because of the double attribute of geothermal resources: water resource attribute and mineral resource attribute, it is essential to publish ***basic law on geothermal resources*** which can regulate certain things in the field of development and utilization of geothermal resources. In the meantime, it is supposed to compile ***national industry planning of geothermal resources*** on the basis of national investigation and evaluation of geothermal resources. We should include this planning into National Development Plan and combine it with other industry planning and urban development planning in order to macroscopically regulate the development of geothermal resources and gain the goal of bringing up economical and social benefits. The last one is system construction. Through a series of institutional arrangements, we can raise the standard of geothermal resources industry and form perfect market of exploration and mining rights. We can allocate geothermal resources with market mechanism, such as auction off geothermal resources full of commercial value and introduce geothermal firms which can freely compete with each other. Besides that, we should integrate financing channel, build risk warning system and promote demonstration area construction for geothermal resources. In that way, we can create good policy tools and market environment for the development and utilization of geothermal resources.

4. CONCLUSION

According to the requirement of "3R"principle of circular economy and above analysis, this article builds a cycle model of whole life cycle of the products of geothermal resources on the basis of industry development (Figure 2). This model vividly demonstrates a circular industry chain which takes resources-products-renewable resources as its mode.

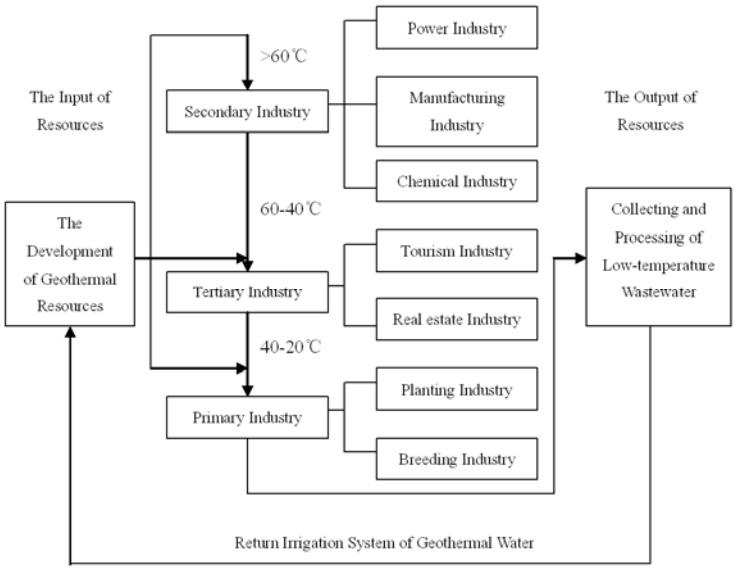

Figure 2: A cycle model of whole life cycle of geothermal resources products on the basis of industry development

Geothermal resources, as the most potential energy of new energies, will play an important role in 21st century. The proposal of circular economy provides a way to scientifically develop geothermal resources for us. A basic development strategy of Chinese geothermal resources in the coming 20-40 years is as follows: clear the functions of government, cultivate the subjects of markets, create a circular economy-oriented geothermal resources industry which is full of international competitiveness in a planned market economy and form the new energy economy, the geothermal resources economy in particular.

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