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A Critical Analysis of Geothermal Industry in China: a Diamond Model Study

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ABSTRACT

Geothermal energy is a clean energy to mitigate greenhouse gas (GHG) emissions as its use can lead to lower mitigation cost. With massive resource potential and commercial prospects, the development of Chinese geothermal industry is exceeding expectations. However, research on incentive policies of geothermal industry is scarce. This paper describes the effect of the geothermal industry in China. We adopt a diamond model in this study to analyze factors that have significant impacts on the development of China's geothermal industry. These factors include: factor conditions, demand conditions, chance, firm strategy, structure and rivalry, related and support industry and government. Each factor identified in the model affects the competitiveness of geothermal industry from different angle. Therefore, factors should be enhanced for the long-term development of geothermal industry.

1. INTRODUCTION

As one of cleaner sources of energy, geothermal energy is an alternative to the hydrocarbon and it has gained extensive attention (Kana et al., 2015). Although geothermal energy is usually considered as a renewable source of energy, its degree of renewability depends on the rate of heat extraction and regeneration. Excessive extraction of heat can accelerate the depletion, reduce reservoir productivity, and in some situations lead to the subsidence. In the absence of policies aimed at promoting sustainable use of the reservoir for the foreseeable future it is quite possible that the thermal properties of the resource will be reduced to a level that cannot support electricity generation (Malafeh & Sharp,2015).

According to the guidelines, by the year of 2015, the geothermal heating area in China was expected to be 5×10^8 m^2 and the installed capacity of geothermal power generation was hoped to reach 100MW; the total used geothermal energy would be equivalent to the energy produced by 2×10^7 tons of standard coal. The utilization of geothermal resources was expected to 5×10^7tce by 2020. It is critical for China to utilize geothermal energy for sustainable development, as China is the largest country in energy consumption and the second largest economy in the world (Jin et al., 2010; Ma et al., 2012).

Scholars have done extensive research on the technologies which affect the geothermal industry in China. They adopted the quantitative and qualitative methods to analyze the technologies and make economic assessment of the geothermal development and utilization. While the technical feasibility of geothermal energy system may be visible in the most studies of geothermal energy, the risk and initial investment of geothermal energy are very high and the benefit achieved by geothermal industry cannot be realized until 10 to 30 years. In China, there are many manufacturers related to the hot spring and heating industry, but the scale of manufactures is small and they develop slowly. Therefore, this paper adopts a diamond model approach to analyze the situation of the geothermal industry in China. Main focus is placed on investigating how main elements in the model affect the competitiveness and development of China's geothermal industry.

2. DIAMOND MODEL

Porter's diamond model is an effective methodology to analyze the competitive advantages of a national industry. As shown in Figure 1, a diamond model consists of four major components, i.e. factor condition; demand condition; related and support departments; and firm strategy, structure and rivalry, as well as another two accessorial factors: government and chance(Porter, 1990).The "factor condition" often provide initial advantages. As measures of sophisticated and demanding local customers, the "demand condition" influence the pace and direction of innovation as well as product development. The "related and support departments" considers the supply chain aspect of an industry, e.g. the accessibility to quality suppliers. And firms often enjoy advantages such as cost efficiency and innovative inputs if a mature support industry exists. The "firm strategy, structure and rivalry" are the local context and rules that encourage investment and sustained upgrading, the incentive systems across all major institutions, and the open and vigorous competition among locally based rivals (Zhao et al., 2009). The diamond model fully summaries the factors that affect the competitiveness of an industry (Zhao et al., 2011). The model highlights the firms' strategies and the government behaviors so that how an industry can improve its competitiveness according to the identified factors. This paper analyzes China's geothermal industry using the diamond model.

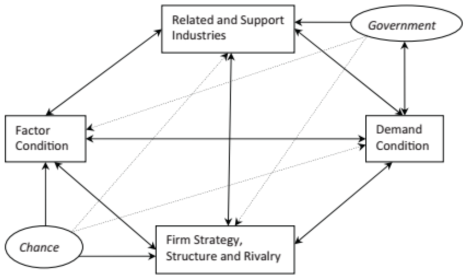

Figure 1: Diamond model

3. DIAMOND MODEL ANALYSIS

3.1 Factor condition

3.1.1 Geothermal utilization of geothermal energy

China, one of the earliest countries to make use of geothermal energy in the world, has a history of more than 2000 years on the utilization of geothermal energy, especially hot springs. Direct use of geothermal energy in China has ranked first in the world for many years. According to the report of the World Geothermal Conference in 2010 and 2015(Zhang &Wei, 2011; Zheng, 2015), geothermal direct use is shown in Table 1. The sum of geothermal heating area reached $6.03 \times 10^7 m^2$ in 2014; the installed capacity reached 2946MWt with annual energy use of 33710TJ which was 1.3 times of the value in 2009 (14798TJ). The total installed capacity of greenhouse heating in 2014 reached 154MWt with annual energy use of 1797TJ which increased by 5.5% in 2009. The total installed capacity of fish farming in 2014 reached 217MWt, equivalent to annual energy use of 2395TJ which increased by 10.3% in 2009. Geothermal energy was widely used in textile, wood, agriculture drying industries as well as in mineral water production (Zhu et al., 2015). In 2014, the total installed capacity of agricultural drying and industrial process heat reached 95MWt and 169MWt, equivalent to annual energy utilization of 1198TJ and 3304 TJ, respectively. Hot springs were used for bathing, swimming and medical care and promoted the investors developing the local tourism, so that hot spring industry was concentrated on tourism, real estate development. The total installed capacity of bathing and swimming reached 2508 MWt with annual energy use of 31637TJ, which increased by 32.4% in 2009. The total installed capacity of geothermal heat pump reached 1178MWt with annual energy use of 100311TJ which increased by 33.1% in 2009. In the development of geothermal, the growth of geothermal heating was the fastest, followed by the development of ground source heat pump.

Table 1. Geothermal direct uses in 2009 and 2014 (Zhang & Wei, 2011; Zheng, 2015)

Use	2009		2014	
	Installed Capacity(MWt)	Annual Energy Use(TJ/yr)	Installed Capacity(MWt)	Annual Energy Use(TJ/yr)
Individual Space Heating				
District Heating	1291	14798	2946	33710
Air Conditioning (Cooling)				
Greenhouse Heating	146	1688	154	1797
Fish Farming	197	2171	217	2395
Animal Farming				
Agricultral Drying	82	1037	95	1198
Industrial Process Heat	145	2733	169	3304
Snow Melting				
Bathing and Swimming	1826	23886	2508	31637
Other Uses (Specify)				
Subtotal	3687	46313	6089	74041
Geothermal Heat Pumps	8898	75348	11781	100311
TOTAL	12585	121661	17870	174352

3.1.2 Geothermal power generation

Geothermal power plants can be basically divided into two groups: steam cycles and binary cycles (Zhou, 2003; Xu et al., 2012). In the steam cycle the geothermal fluid is allowed to boil or “flash” above boiling point by lowering the pressure. After becoming a two-phase fluid, the steam is separated from the brine and expanded in a turbine (Zheng & Pan, 2009). The process of lowering the pressure to boil the fluid is called “flash process”. The binary cycles use a secondary working fluid in a closed cycle. Heat exchangers are used to transfer heat from the geothermal fluid to the working fluid, the working fluid is vaporized and expanded in a turbine, and the cooled geothermal fluid is reinjected to the reservoir (Geirdal et al., 2016). The first geothermal power generation station in China was established in December 1970 in Dengwu village of Fengshun county, Guangdong Province, which marked that China became the eighth country to use geothermal energy for power generation in the world. In 1971, China’s first geothermal binary power station using 67℃ geothermal water with a capacity of 50 kWe was constructed in Wentang village of Yichun county, Jiangxi Province. After that, five medium-low temperature geothermal power stations were built in Hunan, Guangxi, Shandong, Liaoning, and Heibei (Zheng et al., 2015). However, at the end of 1970s, only the power stations in Guangdong and Hunan were in operation (Zheng &Dong, 2008). China’s geothermal power generation has a little progress in recent years due to the application of the screw expander power unit. Jiangxi Huadian Electrical Power Co. Ltd. was dedicated in the development of the total flow system unit. It started the test of 1 MWe unit in 2008 in Yangbajain, then completed the test and yielded electric power in 2009, and added one more 1 MWe in 2010. It made Yangbajain geothermal power plant reached installed capacity of 26.18MWe and yielded 140 GWh per year (Zheng, 2015).

3.2 Demand condition

At present, China has initially formed integrated development utilization system of geothermal energy(Zhao & Wan, 2014). It centers on geothermal power generation and direct use which is mainly for heating and cooling, spa treatment, tourism, agriculture, etc. Geothermal power generation can be divided into conventional power generation and enhanced geothermal systems(EGS) power generation. Conventional type in China usually divided into high temperature(above 150℃) geothermal power generation and low-medium temperature geothermal power generation. Direct use of geothermal energy mainly be divided into heating and cooling of low-medium temperature geothermal energy which includes district heating, air-conditioning, greenhouse heating and industrial process heat and hot springs of shallow geothermal energy which includes bathing and swimming utilization. As to geothermal power generation and direct-use, China Academy of Engineering put forward the development goals in different time nodes (Table 2). As can be seen in Table 2, up to 2050, the scale of the low-medium temperature geothermal direct-use will triple the current value, and the shallow geothermal energy utilization can reach 50,000MWt. The high temperature power installed generation capacity will be promoted, and stress will also be put on the development of the low-medium temperature and the EGS power generation(Zhao & Wan, 2014).

Table 2. Strategic targets of geothermal energy development in China (Beijing, 2011)

Year	Power generation energy development/MWe			Direct Use/MWt	
	High temperature	Low-medium temperature	EGS	Low-medium temperature	Shallow geothermal
Status quo	25.18	0.5	-	3239	3000
2020	75	2.5	Experiment	4000	10000
2030	200	20	25	6500	20000
2050	500	100	200	10000	50000

3.3 Chance

Geothermal projects are designed to be within time, budget, planned specification and legal and regulatory provisions while meeting the project objectives (Ngugi, 2014). The cost of geothermal power development and production is affected by various kinds of parameters. Since power facilities have an expected lifetime, power costs of energy corresponds to the cost of power that amortizes all capital costs incurred over the expected life time of the power plant. The initial capital costs and financial interests are thus spread out over the total amount of energy produced throughout the entire production life of the power facility. The cost have two major components: (1) the initial capital investment and (2) operation and maintenance(O&M) costs (Hance & Gawell, 2005).

The cost for different energy types are listed in Table 3(Li et al., 2015; Annual Energy Outlook, 2016; Kenny et al., 2016). It calculated the levelized costs for new generation resources, plants entering service in 2022 while levelized cost of electricity (LCOE) was often cited as a convenient summary measure of the overall competiveness of different generating technologies which represented the per-kilowatthour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating LCOE included capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type. It consisted of 65.72% of the total system LCOE while fixed O&M cost reached 30.97% in 2022. The cost of geothermal energy would take the smallest cost of all estimated LCOE for new generation resources while the capacity factor would be the highest in 2022. In other words, geothermal generation power has a great potential in the future however the initial investment which was related to surface survey and drilling evaluation and to the need to cover the geological risk at the beginning of the exploration would need a large amount of capital investment. Meanwhile the construction of geothermal power station took 3 to 5 years while it would take more than 10 years from surface survey to power construction (Li et al., 2015).

Table 3. Estimated LCOE for new generation resources, plants entering service in 2022 (Li et al., 2015; Annual Energy Outlook, 2016; Kenny et al., 2016)

Type		U.S. Capacity-Weighted Average LCOE (2015 $/MWh) for Plants Entering Service in 2022						Payback (year)	Construction (year)
		Capacity Factor (%)	Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System LCOE		
Wind		42	43.3	12.5	0.0	2.7	58.5	0.4-1.4	<1
Solar PV		26	61.2	9.5	0.0	3.5	74.2	1-2.7	0.3-0.5
Geothermal		91	27.8	13.1	0.0	1.4	42.3	5.7	3-5
Hydroelectric		60	54.1	3.1	5.0	1.5	63.7	0.5(large) 11.8(small)	10-20 1
Advanced Nuclear		90	75	12.4	11.3	1.0	99.7	-	-
Natural gas-fired	Conventional combined cycle	87	12.8	1.4	41.2	1.0	56.4	-	-
	Advanced combined cycle	87	15.4	1.3	38.1	1.1	55.8	-	-
	Conventional combustion turbine	30	37.1	6.5	58.9	2.9	105.4	-	-
	Advanced combustion turbine	30	25.9	2.5	61.9	3.3	93.6	-	-

3.4 Firm strategy, structure and rivalry

The high price of raw materials, small scale markets, lack of product and technology standards and instable quality are constraining the sustainable development of China's geothermal industry. In this rivalry environment, the common strategy adopted by most China's geothermal firms is to focus on the specialization, the differentiation and the technological innovation. If taking the specialization strategy, the company entirely concentrates on specializing one particular sector of the geothermal industry in order to meet any market changes. In terms of technological innovation strategy, geothermal enterprises devote for the research and development of the core technologies related to geothermal heating and power. Those geothermal companies implementing the differentiation strategy focus on distinguishing from counterparts by means of branding and marketing of key products and technologies.

The developing potential of the geothermal industry is massive however the industry standard is not comprehensive and the market access threshold is lower than the traditional heating and power industry. As long as having certain amount of funds, many firm can enter the industry. As a result, there are hundreds of geothermal companies operating in China at the moment, whereas this number is increasing constantly. Above all, there is fierce competition among geothermal companies in China's geothermal industry.

3.5. Related and support industry

The geothermal industry chain includes the equipment manufacturing, the power plants and other heating device. The competitiveness of the geothermal industry will largely depend upon the development level of all related and supporting industries. Currently the major types of geothermal heating industry include the pumps and drilling equipment.

3.6 Government

In order to guarantee the development of geothermal industry, Chinese government formulated a series of policies and regulations (Table 4). In 2002, Ministry of Land and Resources pointed out that the geothermal resources was one of the most important clean energies and the government planned to promote the geothermal industry. Implementing "Renewable Energy Law" in 2006, the government explicitly stated the importance of geothermal development and encouraged enterprises to develop the geothermal energy. After that, China attached great importance to the development and utilization of geothermal energy. China's National Energy Administration, Ministry of Finance, Ministry of Land and Resources, and Ministry of Housing and Urban-Rural Development jointly issued a document named "Guidelines on promoting of geothermal energy development and utilization" in January 2013 which was the first and complete document as an incentive for geothermal industry in China. It referred that the government should give the subsidies to the geothermal power generation.

Table 4. Policy and regulations for China's geothermal industry (Zhao & Wan, 2014; Miao, 2015)

	Law or regulation	Time	Contents
1	Notice of the Ministry of land and resources on Further Strengthening the geothermal mineral water resources management	Dec. 2002	The geothermal resource is a valuable mineral resource as one of the important clean energy. Promotes the survey geothermal resources exploration; strengthen the development and utilization of geothermal resources and protection; develops geothermal projects and ground water recharge to realize the sustainable utilization of geothermal resources ".
2	Guidelines of Renewable energy industry development	Noe. 2005	Lists geothermal power generation, geothermal heat pump as the key projects and geothermal drilling equipment as the recommended device
3	Renewable energy law	Jan. 2006	Lists geothermal energy development and utilization into the scope of encouraged new energy development
4	National Long-term Scientific and Technological Development Plan (2006-2020)	Dec. 2005	Promotes development and utilization of geothermal energy as a key field
5	Technical code for ground source heat pump systems	Jan. 2006	Provides specification for the design, construction and acceptance of ground source heat pump system projects and ensuring safe and reliable system operation
6	Land and resources "eleven five year" plan	Apr. 2006	Increases the intensity of mineral resources exploration, carries out geothermal hot dry rock resources potential evaluation, and designs the prospective development zone
7	The decision of the state council on energy saving	Aug. 2006	Proposes to make great efforts in the development of renewable energy source, including wind, solar, biomass, geothermal and water energy
8	Interim Measures for the administration of special funds for the development of renewable energy	Aug. 2006	Strengthens the management of special funds for renewable energy development, focuses on supporting the development and utilization of fuel ethanol, biomass, solar energy, wind energy and geothermal energy; focus on the application of solar energy, geothermal energy in buildings
9	Notice of the ministry of construction and the ministry of finance on the implementation comments for application of renewable energy in building	Aug. 2006	Lists ground source heat pump application among key technological fields
10	Comprehensive working program on energy saving and emission reduction	Jun. 2007	States that the energy structure adjustment and the scientific research development and construction of building integrated with geothermal energy shall be actively promoted, and the resource investigation and assessment shall be enhanced
11	Chinese National Climate Change Program	Jun. 2007	Points out that the promotion and protection of water resources to meet the environmental requirements of the geothermal heating and ground source heat pump technology
12	National Renewable Energy Long-Term Planning	Sept. 2007	Puts forward to promote large-scale application of solar energy and geothermal energy in buildings.
13	Ordinance on civil-building energy conservation	Aug. 2008	States that China encourages and supports geothermal energy application
14	Notice on the promotion of shallow geothermal energy development and utilization	Dec. 2008	Makes deployment for the promotion of survey assessment, development and utilization planning and monitoring of shallow geothermal resources
15	Scheme of "Twelfth Five Year" comprehensive energy-saving emission reduction work	Aug. 2011	Adjusts energy structure to develop wind energy, solar energy, geothermal energy and other renewable energy
15	"Twelfth Five-Year Plan" in renewable energy development	Aug. 2012	Promotes the reasonable development and utilization of geothermal energy, and points out to construct the key geothermal projects for electricity and direct use
16	National " Twelve Five-Year " energy plan	Jan. 2013	Increase proportion of geothermal energy use in buildings
17	Guidelines on promoting of geothermal energy development and utilization	Jan. 2013	Sets a goal for geothermal energy development and utilization in 2015 and 2020, refers to the key tasks and subsidy policies

4. CONCLUSIONS

This paper analyzes the competitiveness of the geothermal industry of China via a diamond model approach. China is paying attention to the industry's constantly changing environment, and formulating strategies accordingly. The results show that the geothermal industry has great potential for future world energy supply. The business knowledge in the field is increasing fast and the number of enterprises in geothermal industry is growing. China's geothermal energy potential is tremendous and Chinese government considers energy conservation and emission reduction as a national development strategy. China has positive policies with geothermal subsidies to promote geothermal industry.

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