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Current status and potentials of enhanced geothermal system in China: A review

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ABSTRACT

This research focuses on the enhanced geothermal systems (EGS) potential in China and related technology, especially induced microseismicity and carbon storage combination. Hydraulic fracturing mechanisms applied in EGS were compared with similar fracturing mechanisms for shale gas. Besides, geothermal gradient in China was mapped based on the most recent heat flow values with interpolation method. The development history of geothermal plants in China was comprehensively reviewed through case studies. This paper revealed that the geothermal measuring wells in China were too shallow and too few to offer an accurate estimation. A coming work should aim at heat flow survey in deep layer, induced microseismicity mechanisms, and economically feasible scope in China. These problems will strengthen practical understanding and facilitate extensive application of EGS in China.

Contents

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1. Introduction

With the fast economic development in China, the demand for energy grows rapidly. In 2011, China contributed 71% of the increase in the world energy consumption, and according to the recent report [1] China was ranked first in the total energy consumption of the world. In the energy composition of China, coal-fired power was still the primary energy source and its percentage was about 81.3% in 2010 [2]. The combustion of coal, however, produces large amounts of carbon dioxide, sulfur dioxide and nitrogen oxides, which definitely do harm to human health and ecological environment. As for the other main fossil fuels, China imported 252.9 million tons of crude oil (which constituted 54.76% of the total oil consumption in China [1]) to satisfy the increased demands. The excessive dependence on such imported energies is detrimental to the economy, politics, ecological environment and national security of China.

To obviate or alleviate the over-reliance on conventional energies, China invested heavily in the renewable and sustainable energy such as wind power and solar power particularly in the past decade. Up to 2012, China had cumulatively installed wind turbine capacity of 62,412 MW (MW), ranked first in the world. The cumulative installed solar photovoltaic (PV) power in China was 3000 MW in 2011, an increase of 275% compared to the year 2010. In contrast, the installed geothermal power capacity in China was only 24 MW which remained unchanged for nearly two decades, far less than the capacity of U.S., 3112 MW in 2011 [1]. This great contrast is shown in Table 1.

As we see from Table 1, China was the lowest one among five selected nations not only for the percentage of geothermal energy in the total renewable energy, but also for the net amount of geothermal energy. The geothermal energy was used widely in China, but mainly for direct-use applications such as spas and residential heating. Statistics [3] showed that in China the total direct use of geothermal energy in 2010 was 75,348.3 TJ, which was the largest amount in the world. These statistics indirectly reflect that geothermal energy potential has not been fully exploited yet in China, especially as some important usages such as electricity generation.

In fact, geothermal utilization and geothermal plants are not new in China and their history can be traced back to 1970s [4]. However, most of the plants were shut down years later due to corrosion and clogging of the pipeline. So far, only the Yangbajing power plant is still running and generates nearly 24 GW per year. As shown in Fig. 1, it indicated that geothermal power only takes 0.0013% in the primary energy production in China. The delay in the development of geothermal power in China was attributed to the high initial cost and the limited technologies in China.

Enhanced geothermal system (EGS) represents a series of technologies, including resource exploration, hydraulic fracturing, directional drilling, and seismicity monitoring methods. Traditional hydrothermal power plants generate electricity by exploiting the natural hot water in the geothermal fields. However, in some geothermal fields, the temperature of deep rock is high, but its permeability is low, or the formation lacks enough stored water, which is unfavorable to energy production. In this case, various engineering methods are applied to increase the permeability and expand the heat transfer area in the reservoir. For instance, cool water is injected to stimulate a man-made reservoir and the heated water is used to generate electricity. Overall, by EGS, the productivity of an existing geothermal power plant can be increased and more geothermal fields, which are traditionally viewed unsuitable for power generation, can be developed commercially.

With great potentials, EGS also has some problems. To clarify EGS technological and economical feasibility, and to evaluate EGS potential in China, this study reviewed the status of research about EGS induced microseismicity [5–11] and the feasibility of using CO_2 as a working fluid [12–18]. According to geothermal gradient map and geological conditions in China, recommendations and directions for EGS development in China were provided at last.

Table 1
Cumulative installed renewable energy capacity (MW) and percentage of geothermal energy in total renewable energy in 2011 [1].

2011	China	U.S.	Italy	Japan	Mexico
Wind	62412	47084	6743	2595	1123
Solar	3000	4389	12782	4914	41
Geothermal	24	3112	863	502	887
Percentage (%)	0.037	5.701	4.233	6.267	0.432

2. EGS projects and technologies in the world

2.1. EGS projects in the world

Since the first hot dry rock (HDR) project in Fenton Hill [19], more and more countries have initialized their research and development on EGS. Among the EGS projects, some famous ones are listed in Table 2.

The experiences of existing EGS projects are constructive for future research and development. For example, through the Fenton Hill [19] project, it showed that the stimulated rocks usually fracture along the least principal stress direction. In addition, the Fenton Hill project indicated that building only one production well near a single injection well could be tremendously wasteful. As a result, later projects often applied two or more production wells around an injection well to make full use of the injected fluids. However, a comprehensive optimization on the distance between an injection well and the production wells is often necessary. When the distance is long, the heat transfer areas are huge, leading to high geothermal mining productivity. In contrast, when the distance is small, the water loss can be reduced further [26]. It needs to search for an optimization point between geothermal mining productivity and water loss rate. Besides, other difficulties may be encountered in these projects, such as the relative locations between the well and the fault, the precipitation problems, and so on [27]. The most critical difficulty, however, was the induced

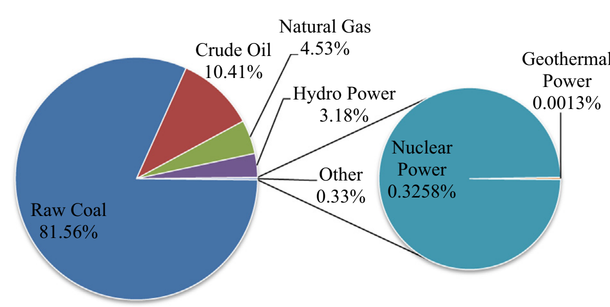

Fig. 1. Composition of primary energy production in China (2010) (Data from [2]).