Present Status and Future Plans of the Geothermal Energy Master Program of NEP-II in Taiwan

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ABSTRACT

Geothermal Energy is a thermal energy source generated from the Earth. It is a type of green energy because of the following characteristics: (1) clean, sustainable, and renewable; (2) could replace nuclear power plants; (3) low power prices; (4) small spatial requirements for geothermal power plants; (5) resistant to natural disasters (nine geothermal power plants in the Northeast were not damaged by the earthquake in March 2011 in Japan). Taiwan is located on a pacific tectonic plate boundary, and the volcanic activity and plate extrusion generate rich geothermal reserves that have high potential for development. According to previous exploration data, the potential electricity generated from traditional shallow geothermal resources may amount to approximately one GWe. However, Enhanced Geothermal Systems (EGS) could increase the geothermal resources across all islands to up to 160 GWe. Therefore, the National Energy Program – Phase II (NEP-II) established a Geothermal Energy and Gas Hydrate Focus Center in 2014 to better support and coordinate Taiwan's geothermal investigation efforts into thermal energy generation. Priority areas for investigation are northern Taiwan, Tatun Volcano Group (TVG), and Ilan, and exploration and drilling is being conducted to obtain critical information and to assess the geothermal resource potential. Eventually, we plan to build the first demonstration geothermal power plant in Taiwan.

Background

Taiwan suffers from a shortage of energy and mostly relies on energy imports from other countries, with up to 98 % of its domestic energy being imported. Analysis of the energy sources used by the Taiwan power company, Taipower, in 2013 revealed that thermal power generation accounted for 71.8% (coal 38.4%, natural gas 31.1%, and fuel oil 2.3%) of power produced, while nuclear and other forms of power generation (cogeneration 3.4%, renewable energy 4.5%, and pumped storage 1.5%) made up 18.8% and 9.4%, respectively. Compared to nuclear power plants, coal-fired power plants release large amounts of pollutants, amongst them the greenhouse gas CO_2, which contributes to the greenhouse effect. However, the Fukushima nuclear disaster caused by the earthquake in Japan in March 2011 made national governments reconsider the safety of nuclear power. Therefore, the new energy policy for Taiwan includes the "guarantee of nuclear safety, prudent reduction of nuclear energy use, creation of green-energy, low-carbon environment, and gradual phasing-out of nuclear energy." To achieve these goals, Phase I of the National Energy Program (NEP-I) was established in 2009. Based on the foundational research in NEP-I, the main development goals of NEP-II (started in 2014) have been initially set as follows: (1) Improvement of energy efficiency and reduction of dependence on imported energy; (2) Improvement of the international competitiveness of alternative-energy industries; (3) Development of smart-grid technologies and promotion of the smart-grid industry; (4) Development of offshore wind power and ocean energy technology industries; (5) Development of clean geothermal energy; (6) Investigation and survey of gas hydrates; and (7) Establishment of CO_2

capture, utilization, and storage (CCUS), and of a new combustion-system industry. Here, we present the status and future plans of the Geothermal Energy Master Program (GEMP) of NEP-II in Taiwan.

Mission and Vision

The overall objectives and strategies of GEMP are exploration, drilling, reservoir engineering, and process engineering to develop the technology and methodology required for geothermal energy usage (Figure 1). The main missions of GEMP include: (1) Review and re-assessment of the currently existing geothermal fields, and construction of traditional power plants to exploit shallow geothermal sources in Taiwan; (2) Development of exploration and exploitation techniques for Enhanced Geothermal System (EGS); (3) Analysis of potential environmental impacts of deep geothermal energy exploitation; and (4) Transfer of well-developed geothermal-energy techniques to commercial companies. The short-term goals (2014-2018) are to construct traditional shallow geothermal power plant, and develop the building concept for a pioneer EGS power plant.

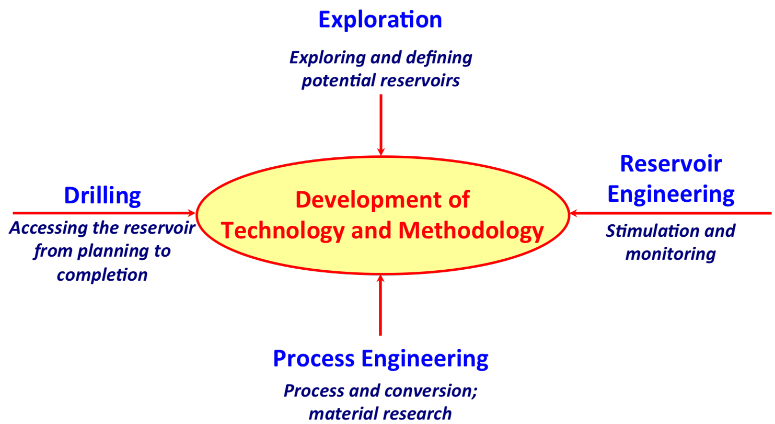

Figure 1. Overall objectives and strategies of GEMP.

Research Highlights and Key Technologies

1. *Construction of 3D Images of the Subterranean Geology in Ilan (Figure 2)*

To create a 3D conceptual model of Ilan's geology, we combined exploration data such as Digital Elevation Models (DEM), regional bedrock isodepth, geological structure, and reflection seismic profiles, and used the programs TOUGH2-EGS and Matlab to develop the model (Chen *et al*., 2015).

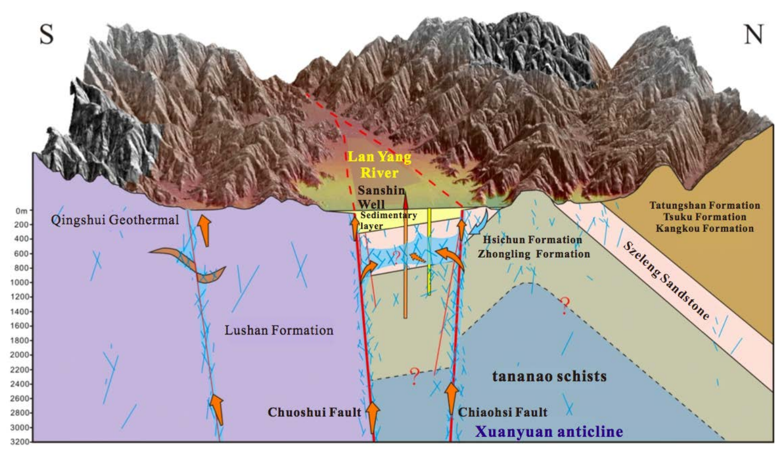

Figure 2. Conceptual 3D geological model of the Sanhsing Hongchailin area, Ilan.

2. *Measurement of Borehole Temperature and Pressure*

We used a novel measurement system that was independently developed in Taiwan. This system uses the fiber optic system "Fiber Bragg Grating" as the measuring device's sensor because it meets the flexibility requirements of exploration and can both measure temperature continuously and create a pressure profile. The suitability of this system was demonstrated in the carbon dioxide injection well in Changhua Coastal Industrial Park. (Chen *et al*., 2015)

3. *Mineral Scaling Simulation System*

We used a novel system created in Taiwan, which uses slate and spring water to simulate mineral scaling to conduct simulated solubility experiments. The results showed that lower reservoir temperatures require injection of more recycled water to maintain reservoir pressure. Therefore, reservoir water capacity is the main factor for determining reservoir pressure (Chen *et al*., 2015).

4. *Material Technology for Anti-Corrosion Coating to Prevent Acid Damage*

An anti-corrosion coating material was developed to overcome the acid fluid problem in the Tatun Volcano Group (TVG) area. Acid-induced weight loss of coatings made from the new material that was coated on stainless 304 is as small as that of titanium in low-pH fluids (Liu *et al*., 2014).

Current Results

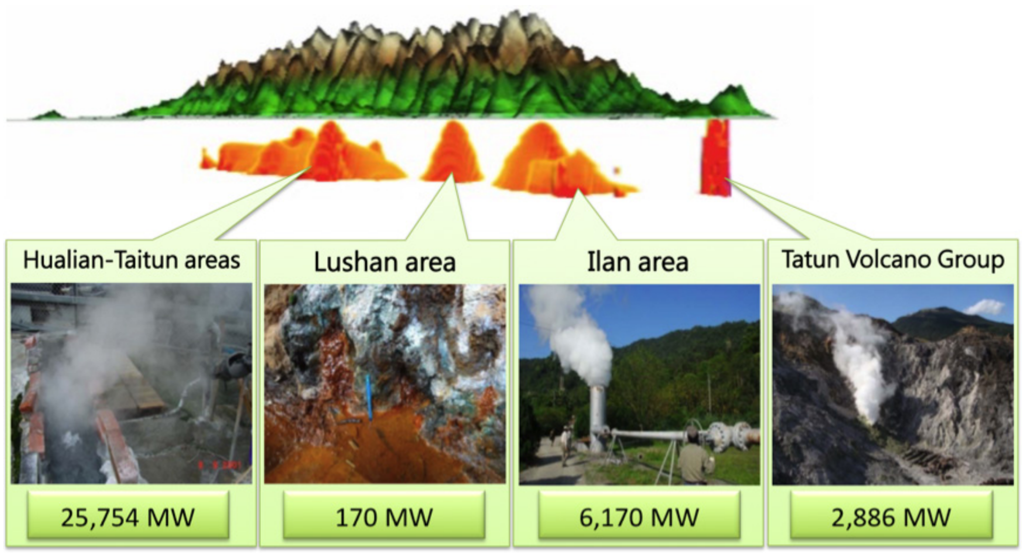

Figure 3. Four geothermal areas with high energy-generation potential in Taiwan, and their expected energy-generating capacity. Estimations were based on elevations of < 1000 m, depths of < 4000 m, and reservoir temperatures of >175 °C.

The implementation strategy of GEMP is divided into two parts, namely shallow and deep strata, based on the distribution of geothermal energy in Taiwan. We integrated and analyzed previous exploration data, including geothermal geology, geophysics, geochemistry, geothermal gradient, and findings from shallow drilling. The results showed that Taiwan has geothermal resources with high potential for energy generation distributed over four major areas, namely the northern TVG, northeastern Ilan Plains, central Lushan, and eastern Hualian-Taitun. The geothermal energy-generating capacity may total 33.6 GWe (Figure 3). Next, we prioritized the exploration and development in of geothermal energy in northern Taiwan because of its high energy requirements for domestic and industrial use. In addition, exploration is easier and faster in northern Taiwan because it is less mountainous. Consequently, the development of shallow geothermal systems is focused on the TVG and Chingshui area, whereas deep geothermal surveys are focused on the Ilan Plains. To date both research approaches have been completed geological surveys for one of the exploration areas, and wells have been drilled. The results are shown in Table 1.

Table 1. Progress of the drilling surveys in northern Taiwan.

	Shallow geothermal system	Deep geothermal system
Major exploration area	Tatun Volcano Group	Ilan Plains
Geothermal type	Volcanic	Non-volcanic
Expected reserves	500 MWe	6.2 GWe (Within elevation of 1,000 m)
Expected exploitation	150 MWe (2020)	-
Reference/ execution team	ITRI, Taiwan	Universities, Taiwan
Drilling location	Sihuangziping, New Taipei	Sanhsing Hongchailin, Ilan
Well number/ depth	1 (traditional)/ 1,300 m	1+1 (EGS)/ total 5,000 m
Current results	By December 2015 a drilling depth of 600 m had been reached and well temperature was approximately 120 ℃ as measured by strata logging.	By March 2016 the first well had been completed, with a drilling depth of 2,225 m. Strata logging after 74 hours revealed a well-bottom temperature of 68.5 ℃, and the temperature gradient within a depth of 2070~ 2200 m was 4.8 ℃/100 m.

Future Plans

In 1980, a geothermal power plant with a generating capacity of three MWe was built at Ilan Chingshui; however, its generation capacity gradually decreased and was eventually shut down after operating for many years. The key impact on power generation is pipeline blockage due to mineral scaling. In recent years, the Chingshui geothermal power plant was repaired and commercial operation was attempted. To this aim, the Ilan County Government proposed a ROT (Reconstruction, Operation, and Transfer) project in 2012 hoping that domestic and international industries will invest in and develop the geothermal power plant in Chingshui. In addition, drilling surveys in Sihuangziping and Sanhsing Hongchailin are in progress to confirm the exploration data. We will therefore import the overall concept and related technologies by implementing bilateral or multilateral cooperation projects, and promote the development of geothermal power plants in Taiwan.

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