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Current Developments of the Geothermal Energy in Taiwan

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ABSTRACT

Taiwan, which is located Located in the pacific rim of fire, possesses abundant geothermal resources in terms of geological processes, such as the volcanic activities and rapid uplifting terranes due to plate subduction and arc-continent collision. Based on previously available exploration before the 1980s, Taiwan may have about 1 GWe of potential shallow geothermal energy, which is less than 3% of the national gross power generation. Meanwhile, the deep geothermal potentials for EGS are about 33.6 GWe in this Island. To reduce the emissions of greenhouse gas (GHG) and pollutions of PM 2.5, and to approach as the nuclear-free country, Taiwan sets up an energy portfolio standard to be as 20% renewable, 30% coals and 50% natural gases in 2025. Among the renewable energy, the geothermal energy will install more than 200 MWe to produce about 1.3 billion kWh per year in 2025. However, it is just a 300 KWe geothermal power plant now and needs to speed up to catch up on the schedules. Currently, there are planning to develop 150 MWe geothermal power plants in 5 counties of Taiwan in 2020. Among them, north Taiwan is one of the largest sites to install power plants about 100 MWe. Several teams, including private and national ones to do explorations and exploitations national wide in Taiwan.

1. INTRODUCTION

Taiwan is characterized by a shortage of energy sources. The country mostly relies on imports of energy sources from other countries. The proportion of imports to domestic energy production is as high as 98%. Besides, the local manufacturing industry is export-oriented, and the energy demands of the population and the industrial sector are consistently high. A stable supply of low-price energy is, therefore, a necessary prerequisite for the economic development of Taiwan. An analysis of the installed capacity and power generation ratio of Taiwan Power Company (TaiPower) in 2018 reveals that fossil fuel-based power generation accounts for 71.8% (coal 38.4%, natural gas 31.1%, fuel oil 2.3%), while nuclear power generation and other forms of power generation (cogeneration 3.4%, renewable energy 4.5%, pumped storage 1.5%) make up 18.8% and 9.4%, respectively (Table 1 and Figure 1).

Geothermal energy is clean and eco-friendly since it is derived from the inexhaustible thermal energy emitted by our planet. It represents a renewable energy form which can be used directly or converted into electricity. The area of land required is extremely small, and the extraction of geothermal energy does not destroy the original ecology of the natural environment. Geothermal energy can also serve as base-load electricity and as a substitute for fossil fuels. Taiwan, thus, provides outstanding opportunities, such as guaranteeing the electricity price by Feed-in-Tariff (FIT) (BOE, 2018), subsidizing the funds for explorations and drillings (BOE, 2018), and investing much money on R&D for geothermal developments.

Table 1: Present and planned production of electricity in Taiwan (2018)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Solar and Wind)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	0.3	0.023	117,295	49,414	14080	1,560	13,524	8,366	12,918	2,210	157,819	61,549
Under construction in December 2019	4.2	0.33	117,295	49,414	14080	1,560	13,524	8,366	12,918	2,210	157,819	61,549
Funds committed, but not yet under construction in December 2019	150	177.4	non	non	2100	4700	non	non	8,625	17,700	10,875	23,400
Estimated total projected use by 2020	4.5	0.35	117,295	49,414	14080	1,560	13,524	8,366	12,918	2,210	157,819	61,549

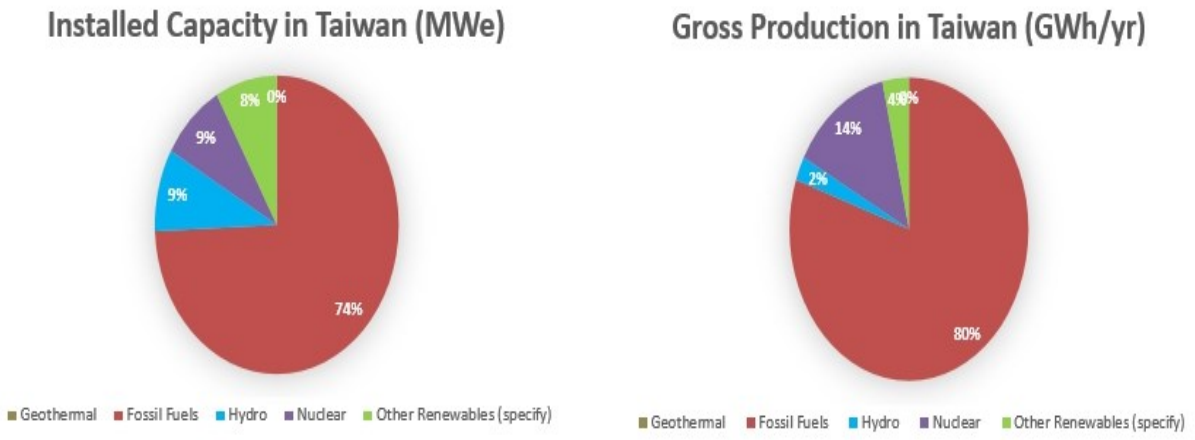

Figure 1: Present production of electricity in Taiwan (data from Taiwan Power Company, 2018).

2. GEOLOGY BACKGROUND

Due to inental plate and the Philippine oceanic plate, presently, the Philippine Sea plate is moving towards WNW at about 70 mm/yr (Seno and Maruyama, 1984), and it is believed the mountain-building process is still going on (Tsai et al., 1981; Yu and Chen, 1994). A dominant collision zone frequently inducing folding and fault thrusting in the area may exist in central Taiwan since the last 5 Ma (Ho, 1986; Teng, 1987, 1990). At the latitude of southern Taiwan, the Philippine Sea plate is riding up over the continental shelf of the South China Sea, which it causes rapid uplift with high geothermal gradient to create the Taiwan mountain range. In northern Taiwan, the Philippine Sea Plate is subducting into the Eurasia Plate to generate a Ryukyu arc and Okinawa Trough, which extend southwestwardly from Japan into north Taiwan. Therefore, the active volcanoes and rifting basin occur in the north part of this Island (Song et al., 2000; Teng, 1996; Wang et al., 1999, 2004). Tectonically, no matter what viewing from the north to the south or vice versa, Taiwan is always located at a transition from subduction to a collision. Those complicated tectonic processes create a good condition for high geothermal resources storing underneath Taiwan.

3. GEOTHERMAL RESOURCES AND POTENTIAL

Taiwan, which is located on the Pacific Rim of Fire, have precious geothermal resources due to volcanic activities and plate collision. Taiwan is placed at a plate boundary, and geothermal activity can be observed all over the island, which has rich geothermal reserves. Geothermal exploration has done since the 1960s, but exploration work has already been suspended for many years. Based on available data before 1980, Taiwan may have about one GWe of potential shallow geothermal energy (ITRI, 2012), which is more and less about 2 % of the national gross power generation. Therefore, several small pilot geothermal power plants have been constructed (Table 2) and were terminated by the end of projects or non-economic advantages or the problems being hard to be overcome.

Table 2: Utilization of geothermal energy for electric power generation in Taiwan

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe[3)]	Total Running Capacity MWe[4)]	Annual Energy Produced 2019 GWh/yr	Total under Constr. or Planned MWe
Ilan	Cingshuei	1981-1993	1	Retired	1F	3	1.8	-	
Ilan	Cingshuei	2019	1		B	0.3	0.3	0.256	4.2
Ilan	Toucheng	1985-1994	1	Retired	B	0.26	0.26	-	
Ilan	Toucheng	2022	1	Planning	B	0	0	-	8
Taipei	Hsihuangpin	2022	1	Planning	1F	0	-	-	1
Taitung	Jeben	2021	1	Planning	B	0.03[c]	0.03	0.025	3

N = Not operating, R = Retired. Otherwise, leave blank if presently operating.
1F = Single Flash; B = Binary (Rankine Cycle); 2F = Double Flash; H = Hybrid; 3F = Triple Flash;
O = Other (please specify); D = Dry Steam

A recently released planning report on the NSTP specifies that geothermal energy is an essential type of renewable energy. It is expected that geothermal energy will eventually have an installed power capacity of 7.15 GWe, which is equivalent to 14.65% of the national installed capacity that currently amounts to 48.8 GWe.

The project of geothermal energy research in the Chingshui Area in Ilan County, sponsored by NSTP, has adopted the concept of EGS to reassess the amount of geothermal energy present in deep strata all over the island over the past year and a half. The results reveal that geothermal resources present in Taiwan equal 159.6 GWe (the exploitable quantity amounts estimated up to 33.6 GWe, Table 3) (Song et al., 2012).

Table 3: Estimated power generating capacity of geothermal reserves with geothermal temperatures in excess of 175℃ in the four major geothermal areas of Taiwan

Area	Covered total area (km^2)	Power generating capacity (exploitable) (MWe)	Ratio (%)	Power generating capacity of geothermal reserves at different depths (MWe) (development restricted or unrestricted by natural conditions)				
				> 2000m	1500-2000m	1000-1500m	500-1000m	< 500m
Ilan plain	532	36,923 (6,170)	23.13%	30,219	13	456	2,100	4,135
Datun Volcano Group	88	2,886 (2,886)	1.81%	0	0	0	716	2,170
Hualien-Taitung geothermal area	5,403	100,431(25,754)	62.92%	15,900	43,334	15,443	12,880	12,874
Lushan Geothermal Area	954	19,366 (170)	12.13%	10,143	5,194	3,859	170	0
Total amounts for all four areas (Ratios in %)	6,977	159,606 (33,640)		56,262 (35.25%)	48,541 (30.41%)	19,758 (12.38%)	15,866 (9.94%)	19,179 (12.02%)

* Development possible at depths below 1,000m except in the Yangmingshan National Park area where development is forbidden (1,405 MWe must be deducted)

4. GEOTHERMAL ENERGY DEVELOPMENTS IN TAIWAN

Taiwan is an economically developed country, which needs to build up all kinds of power plants to generate huge gross electricity stably for family and industrial uses (Table 1). Meanwhile, Taiwan is located in the tropical and subtropical areas and does not require to provide the spacing heating for winter. Therefore, the geothermal energy provides for generating electricity, but almost it is not for direct uses, except for some hot spring swimming pools for spa and thermal therapy in Taiwan (Table 4).

Currently, it is just a 300 KWe geothermal power plant in Taiwan. However, the Bureau of Energy, Taiwan is planning to develop 150 MWe geothermal power plants in 5 counties in 2020 (Fig. 2), and to be up 200 MWe in 2025. Among them, north Taiwan is one of the largest sites to install power plants about 100 MWe, while the others are about 50 MWe. Those activities, including geothermal explorations, drillings, operations and maintenances should have much workforce (Table 4&5), and invest huge money on them (Table 7). For reaching the targets, Taiwan needs to speed up for developing and installing the geothermal power plants quickly. Several teams, including private and national ones, make more explorations and exploitations widely in Taiwan, currently (Table 2).

Figure 2: The planning installing geothermal power plants of Taiwan in 2020 (BOE, 2018).

Table 4: Well drilled for electrical, direct and combined use of geothermal resources from January1, 2015 50 December 31, 2019

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)		0	0		
Production	>150° C	5[a]	0	0		9.028
	150-100° C	1[b]	0	0		1.46
	<100° C		0	0		
Injection	(all)		0	0		
Total			0	0		

Table 6: Total investments in geothermal in (2019) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1966-1972[a]	2798000		non	non	0	100
1973-1979[a]	3608000		non	non	0	100
1980-1984[a]	6862533		non	non	0	100
1985-1990[a]	3851833		non	non	0	100
1991-1994[a]	1566667		non	non	0	100
2005-2008[b]	8081100	8600	non	non	0	100
2009-2013[c]	4760316	864867	non	non	15%	85%
2014-2017[d]	20823300	9086000	non	non	25%	75%
2018-2019[d]	1,512,333	400,000	non	non	0	100

5. DISCUSSIONS AND CONCLUSIONS

Taiwan is located at the ring of fire, which is rich in geothermal energy. Based on the previous exploration, Taiwan has recoverable potentials of install capacities being about 1 GWe and 33 GWe for shallower traditional and deeper geothermal energy, respectively (ITRI, 2012; Song et al., 2012). Meanwhile, the geothermal explorations have been done very early, since 1960'. However, there is almost no geothermal power plant to produce gross electricity until now. Although Taiwan had two pilot or test power plants, those two were small and terminated in early 1990' (Lu et al., 2018). Except for the problems of no-reinjection, scaling and not suitable machine, the main reasons may be the small scale, expensive costs, high risks and limited knowledge of underground geological reservoirs.

Currently, it is the best opportunities for developing geothermal energy for producing electricity in Taiwan. Taiwan has three operated (No. 1, 2 & 3) and one constructing nuclear power plants (No. 4). After 2011 Japan's nuclear disaster event, Taiwanese stood up to say "no nukes" and ask the government to shut down the operated and under-construction nuclear powers. Originally, those three operated plants will be decommissioned in 202018-2019, 2021-2023 and 2024-2025, respectively. However, Taiwan government was planning to extend those life cycles for more 20 years. After this protected event, they were decided to be decommissioned as original plans, and the No. 4 was sealed and no more constructed. Taiwan, therefore, will become a nuclear-free country in 2025. As shown in Figure 1, there are about 14% shortages of gross electricity in 2025 (Taipower, 2018). Meanwhile, for reducing the emissions of greenhouse gas (GHG) and pollutions of PM. 2.5, and to approach as the nuclear-free country, Taiwan sets up an energy portfolio standard to be as 20% renewable, 30% coals and 50% natural gases in 2025. However, the gross electricity produced by renewable power plants is just about 4.5 % currently (Taipower, 2018). Accordingly, Taiwan should speed up to develop renewable energy for producing gross electricity, including the geothermal power plants.

Also, to encourage explorations and developments of geothermal energy Taiwan, the government takes the FIT system and subsidize more funds for it. The price of electricity for public usages is about NT$ 2.5 (US$ 0.08 cents) in average now, but the FIT one is about NT$ 5.1956 (US$ 0.167 cents), which is over twice for the public electrical bill. Meanwhile, to speed up the geothermal exploitation, the government also subsidizes about NT$ 100 million (~3.22 million USD) for exploration and drilling per project and contributes more funds in research and development (R&D) for academia and private company. Moreover, the Environment Protection Administration (EPA) passes a regulation not necessary to do the environmental assessment for a geothermal power plant with install capacity being less than 10 MWe. It is an excellent advantage for geothermal society because the environmental assessment is very tough procedures and used to be 2-3 years to finish in Taiwan.

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