TAIWAN i-GEOTHERMAL ENERGY SYSTEM

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ABSTRACT

Taiwan has a total of about 128 hot spring areas. 20% of them are high geothermal gradient and have good potential for electricity production. 50% of them produce 50 – 74^{0}C hot spring. If one can use modern technologies to drill deeper, reaching the effectiveness of power generation, and conduct the closed-loop water supply system, these sites may produce economical electricity. In order to achieve the maximum usage of the i-Geothermal Energy System (iGES), we propose to apply 1st stage water of 80 – 120^{0}C for electricity production, 2nd stage water of 60 – 80^{0}C for heating or negative cooling work, 3rd stage water of 40 – 60^{0}C for original hot spring usage, and 4th stage water of 30^{0}C for prawn aquaculture. The remaining water, after treatment, can be recycled and pumped underground to carry new heat back to the surface. The iGES can be pollution–free in both surface and deep. We estimate that, if each i-Geothermal Energy System operator produces 20 MWe of electricity, added to the geothermal energy saving of up to 100 MWe, it will only cost 1/10 of the price to generate 1GWe power, equivalent to that of a nuclear power unit. Taiwan will be a step closer to a nuclear-free state as well as effectively reducing CO_2 emission. The locally generated power can also be used for the regional green communities. It produces a warm and effective living environment. Active plate tectonic environments and frequent earthquakes create an enormous amount of heat that is well distributed throughout Taiwan. They are contained in the intrusive volcanoes, metamorphic belts and plate collision zones. Enhanced by a near 3-meter rain fall per year, Taiwan is one of the ideal sites to develop iGES. The heat coming from the Earth's geosphere is safe, stable, reliable, and pollution-free. It is not only capable of reducing the 99% of Taiwan's import energy need, but also a way to open the closed-loop, hot dry rock energy harvest system, the CEEG system. The future development of CEEG will become part of the major electricity base load.

Keywords: Geothermal, Multiple usage, New energy

1. DEVELOPMENT OF TAIWAN'S GEOTHERMAL RESOURCE

In 1928, there were about 90 geothermal prospective areas in Taiwan (Fig. 1). Due to further investigations by the geological survey and leisure industry, this number has recently been increased to about 128 prospective areas (Fig. 2) and there are 5,000 hot spring operators. Because of the boom of the tourism industry, the hot spring business has rapidly increased. Originally, the hot spring water was directly guided from the nearby geothermal resources. Now, it is mostly accompanied by the drilling. Some of the wells can be reached at a depth of 2,000 m. Taiwan is one of the countries with the most dynamic mountain uplifting geology, therefore, more geothermal fields are found due to the frequent earthquakes, dense faults and metamorphic belts. Between 1970 and 1980, the Taiwan government surveyed the hot spring water areas that registered more than 80^{o}C and established 2 geothermal power plants in I-Lan, East Taiwan. The Tu-Chang Geothermal Power Plant was a binary system plant and the Ching-Shui Plant was a flash steam plant. Both experiments failed in less than 10 years, due to economic and technical reasons (such as the oil price dropped, the maintenance fees were too high and the water pipes were geologically fouled). There was not enough time to overcome the technical problems before both plants were closed. This created a big setback in geothermal energy development from both the human and technical prospective for over 30 years.

Fig. 1. Map showing the distribution of hot springs in Taiwan during the period of Japanese rule (Ziro, 1928)

Fig. 2. Geological map showing the distribution of hot springs in Taiwan at present (CGS, 2002)

2. DISTRBUTION OF TAIWAN'S GEOTHERMAL RESOURCES

According to the 2002 Taiwan Geothermal Energy Report by the Industrial Technology and Research Institute, Taiwan's geothermal fields can be subdivided based on their respective water temperature: (1) boiling hot spring (water temperature greater than 97^oC), (2) high temperature hot spring (75^o - 96^oC), and (3) medium temperature hot spring (50^o - 74^oC). In Taiwan, about 20% of hot springs are in the (1) boiling and (2) high temperature categories. They are distributed throughout areas of Taiwan that consume most power such as Northern Taiwan and most scenic areas in Eastern/Middle Taiwan (Fig. 3). The (3) medium temperature hot springs represent 50% and are located in the foothills of Western Taiwan. These areas are known to be in the mountain building fault zones in which the hot water is more easily mixed with the cold ground water. If we exploit the deep wells to isolate the mixing, the water temperature can be effectively maintained for power generation. Therefore, 70% of Taiwan's geothermal fields can be developed for both power generation and hot spring use. This is a double-win green emerging business. Using new technologies, we will also apply the idea of the Enhanced Geothermal System (EGS; MIT report, 2006) or the Complex Energy Extraction from Geothermal resource (CEEG), to drill 5,000 m and deeper to obtain higher water temperatures (200^o – 300^oC) for high performance of power generation. In this regard, Taiwan can produce economical electricity and enhance geothermal related industries wherever the power is needed. It will reduce our dependence on imported oil and gas which is now 99.4%.

According to the 2012 National Energy Program, Taiwan's geothermal fields have an estimated electricity generating capacity of 7.15 GWe. This is 14.65% of the national total electricity generating capacity (48.80 GWe). Our total nuclear power generation accounts for 10.60%. This means that Taiwan has a good opportunity to use its geothermal energy to gradually replace nuclear energy usage, if we start now. It also means that Taiwan will be a “nuclear-free state” in respect to our "Law of Environmental Protection".

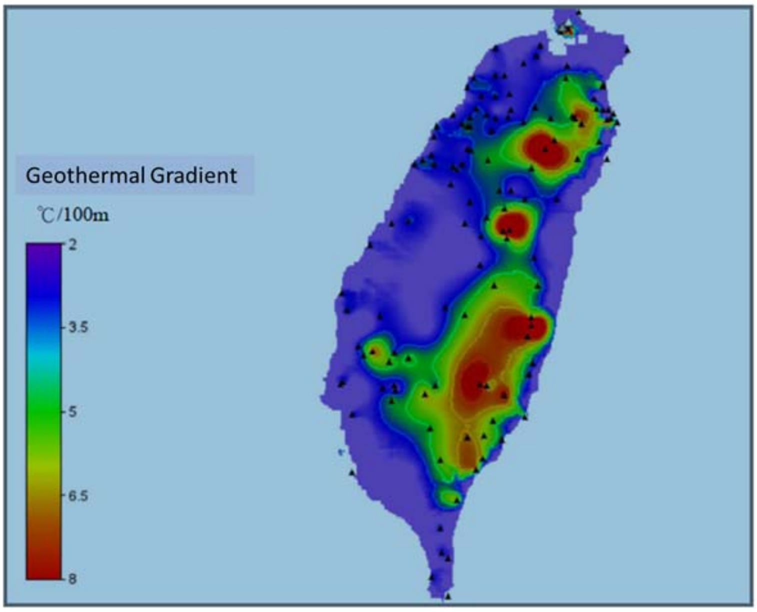

Fig. 3. Taiwan Geothermal Gradient (Liu et al., 2012)

3. TAIWAN iGES

The Taiwanese "Law of Renewable Energy" uses the "Feed-in Tariff" method to encourage the private sectors in developing renewable energy. However, the nuclear energy has a priority in the country's current power generation portfolio. It is, therefore, the renewable energies that are pushed aside. Unlike Japan and the Philippines that utilize geothermal energy to produce electricity and other energy direct-uses, the abundant hot springs in Taiwan, at the moment, are limited to the use by the leisure industry only. Taiwan has a total of about 5,000 spa operators and the numbers are increasing. If the government can induce the private sectors using the modern exploration technology and geothermal power generation, the hot spring water of 60^{o}C and above can be used to produce renewable energy and even create energy-saving air conditioning. The cascade uses of geothermal energy were first developed in 1964 by the Oregon Institute of Technology (such as Fig. 4). We propose to extract the 90^{o} – 120^{o}C water for electricity production, the 60^{o} – 90^{o}C water for heating or negative cooling, the 40^{o} – 60^{o}C water for leisure spa use, and the 30^{o}C water for high-value fish and prawn aquaculture. Finally, the remaining water, after treatment, can be recycled into the deep underground and extract new heat back to the surface. We can also install monitoring sensors and interactive management programs to the system. This is the general concept of an ideal i-Geothermal Energy System (iGES). It produces everything required for a green energy and low-carbon living environment.

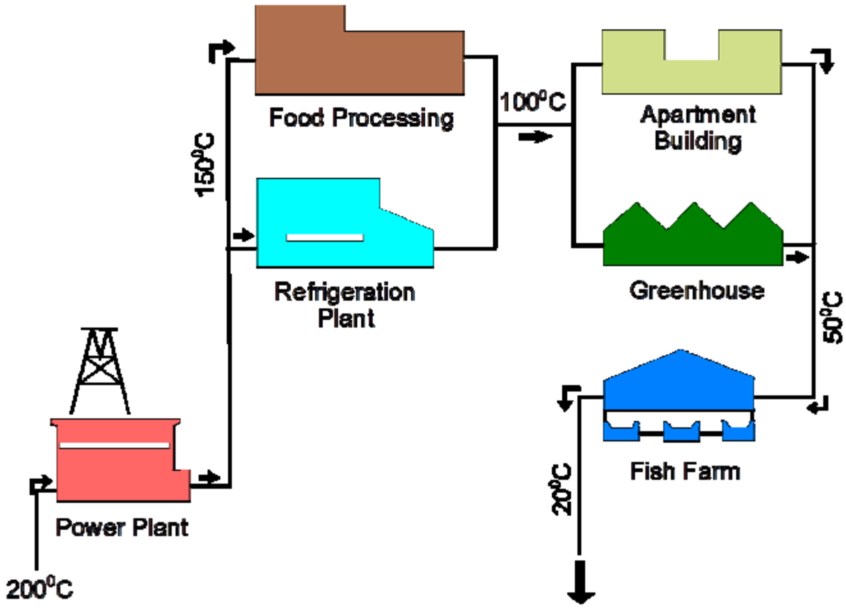

Fig. 4. Cascade uses of geothermal energy (courtesy of the Geo-Heat Center, Klamath Falls, Oregon, USA)

4. SUBSTITUTION OF NUCLEAR POWER RESOURCE

According to the well-known Moody Credit Rating Agency, the estimated set-up costs for a nuclear power plant are about 7,000 US$/KWe (7,000,000,000 US$/GWe, equivalent to 1 nuclear reactor) and the price is increasing due to the extra costs of environmental concerns and insurance. To build a 20 MWe geothermal power plant will cost about US$70,000,000. This means that Taiwan will have a choice of either construct 1 nuclear reactor power plant or set up 100 geothermal power plants at the same cost. 100 geothermal plants will produce twice the electrical power that 1 nuclear reactor can produce. Besides, the geothermal plants can be located in wherever the power is needed. There are also the benefits of less cost and less waste in the electricity network, no restrictions and no cost for importing nuclear resources, and no worry about nuclear waste storage. There is a hope for Taiwan to become a "nuclear-free state" in order to avoid a similar 2011 Fukushima nuclear disaster. We have not even mentioned the additional values of the geothermal applications, such as the cooling/heating energy, leisure spa, and fish aquaculture, etc. The purpose of this paper is to try to convince private investigators to fund a project of $US70,000,000 in setting up the first iGES spa hotel/fish aquaculture/harmonical community in Taiwan. The first potential geothermal field is in the Yang-Ming-Shan National Park in Northern Taiwan. If this funding comes through, other sites can be quickly established in other proper geothermal fields.

The main purpose of this paper is to use a university's vast human and technical resources, combined with active, private investigators who are serving for the community, to make this opportunity into reality.

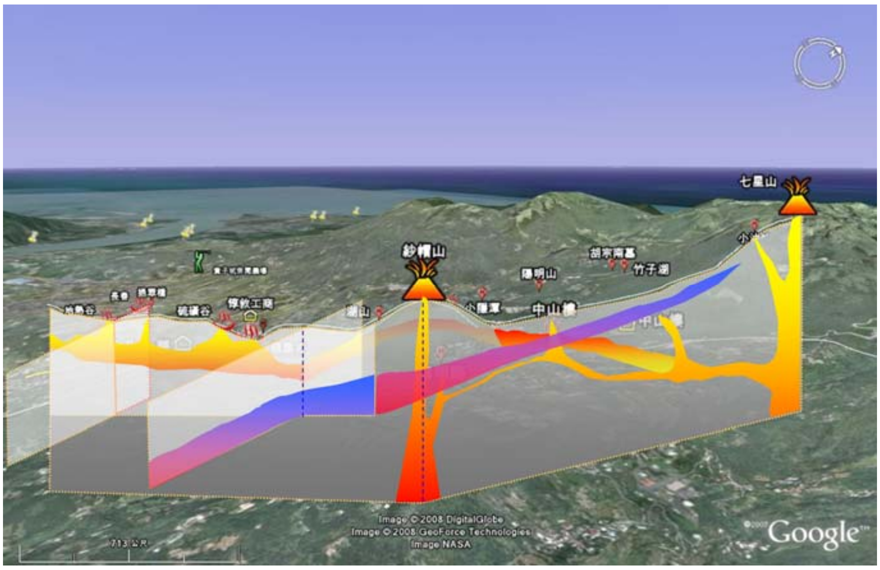

Fig. 5. Schematic illustration of the geothermal system in the Tatun Volcano Group of Yang-Ming-Shan National Park, Northern Taiwan.

5. WARM WATER AQUACULTURE ADDS ADDITIONAL VALUE

Taiwan has a very good experience in fish/shrimp aquaculture, particularly in warm water aquaculture. In the warm water environment, the fish/shrimp increase their activities and therefore, increase the growth rate. Using the remaining hot spring water at 30^{o}C has its merits in terms of utilizing geothermal resources. For example, the best growing temperature for the world's largest fresh water Thai Prawn is about 28^o – 30^{o}C. The spa industry can redirect its remaining water to small size aquaculture farms to create additional value of the geothermal field.

In northern Taiwan and the mountainous region, the winter temperature can drop below 20^{o}C, and sometimes the cold front can even lower the temperature by more than 10^{o}C. In cold weather, fish/shrimps tend to reduce its level of activity, causing retardation of growth rate, poor immunity, lesions, and even low temperature-related deaths. The near-to-constant geothermal water creates an ideal harboring environment for fish/shrimps to survive in the cold winter.

6. FUEL CELL APPLICATION

The geothermal resource can be used for turbine and thermoelectric type power generation, its “taken without a break” heat energy can also be utilized to produce hydrogen which is the major element for fuel cell production. The production process (Fig. 6) is nearly pollution-free and the power efficiency can reach up to 40 – 60 %, which is higher than the physical limitation of 200^{o}C geothermal power generation. Fuel cell and hydrogen production have become the top priorities for energy research and development. Compared to geothermal energy, it has particular benefits such as minimizing the scale of geothermal requirements and maximizing geothermal capacities. Taiwan has a solid industrial base to develop fuel cells via geothermal energy.

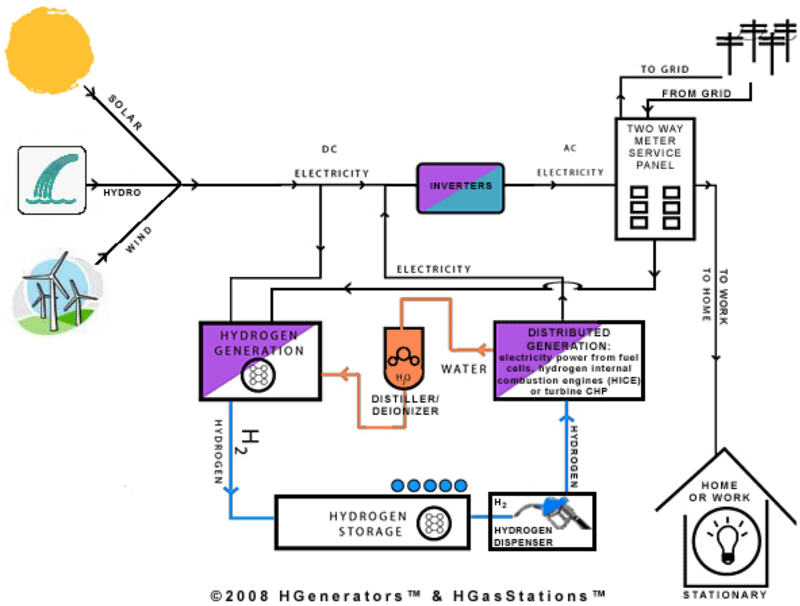

Fig. 6. Sketch of hydrogen generator system combined with renewable energy generators (http://www.hgenerators.com/)

7. CONCLUSION

Similar to Japan, the Philippines, Chile and Indonesia, Taiwan is one of countries with the most dynamic and active plate tectonics environments. The frequent earthquakes create enormous amount of heat that is well distributed underground and are contained in intrusive volcanoes, metamorphic belts and plate collision zones. The heat coming from the Earth's geosphere is safe, stable, reliable, and pollution-free. Enhanced by a near 3-meter rain fall per year, Taiwan is one of the most ideal sites to develop iGES. The main purpose of this paper is to use a university's vast human and technical resources, combined with active, private investigators to serve the best interest of the local community. We conclude:

(1). There are about 128 geothermal prospects and 5,000 hot spring operators in Taiwan and the numbers are increasing.

(2). 20% of the geothermal prospects are located in boiling and high temperature hot spring zones in Northern, Eastern and Middle Taiwan. These can be directly utilized for power generation.

(3). 50% are located in medium high temperature zones distributed in Western Taiwan. By drilling deep wells, we can technically prevent the hot water from mixing with cold ground water. There is tremendous potential for geothermal utilization.

(4). In the future, if we attempt new deep wells and apply EGS/CEEG technology, the geothermal energy plants can be built wherever the power is needed.

(5). By using the cascade steps of geothermal energy utilization, the multiple purposes and needs can be fulfilled by developing iGES in Taiwan.

(6). The potential to use geothermal energy to gradually replace nuclear energy is very high in Taiwan.

(7). Using geothermal energy to produce fuel cells and heat up warm water fish/shrimp farms adds even more value to geothermal energy utilization.

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