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Combining Renewable Energy Technologies - With a Geothermal Focus

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ABSTRACT

Combining renewable energy technologies using their specific characteristics and assets can lead to a more efficient and increased power generation. Geothermal energy being a baseload power source in particular, can enhance the use of other renewables which depend on the availability of wind, sun or hydro resources. Additionally, it can significantly enhance the reliability of a renewable energy future.

Three hybrid systems are introduced and their technical details shown:

1. Ahuachapán power plant, El Salvador (geothermal + solar);
2. Honey Lake hybrid power plant, USA (geothermal + biomass); and
3. Stillwater hybrid power plant, USA (geothermal + solar).

Technical explanations of the plants' set-ups are presented and the combined operations described.

1. INTRODUCTION

Global new investment in renewable power and fuels increased by 17% to a new record of USD 257 billion (REN21 2012). Including hydropower projects of over 50 MW, net investment in renewable power capacity exceeded that of fossil fuels. Renewable energy supplied an estimated 17% of global final energy consumption. The renewable energy resources - biomass, geothermal, hydro, solar, wind, etc. - depend on certain weather, geographic, geological and other conditions. Combining them by using synergy effects and strengths of certain technologies can thus lead to more successful projects. The major advantages of geothermal energy in particular include reliability, compact site development, insignificant emissions and 24/7 baseload power. This paper presents the following three hybrid demonstration projects:

- Ahuachapán power plant, El Salvador: A geothermal field and concentrated solar energy with a prototype array of parabolic mirrors are used for power generation.
- Honey Lake hybrid power plant, USA: Wood chips are the main fuel source of the 34.5 MW plant. Geothermal resources of 116°C are used to dry the wood chips and increase the temperature of the boiler condensate water.
- Stillwater hybrid power plant, USA: For peak addition to the 47 MW geothermal plant a 24 MW solar installation was added.

2. AHUACHAPÁN POWER PLANT, EL SALVADOR

The geothermal energy production in El Salvador dates back to 1975, with the first 30 MW unit in Ahuachapán. In El Salvador geothermal energy has been one of the main sources of electricity, supplying the country with up to 41% of the national electricity demand. In 1981 for example Ahuachapán was the first geothermal field in El Salvador to be developed for commercial electricity generation. Besides two 30 MW single-flash units a third double-flash unit came online in 1981, bringing the total capacity to 95 MW. Ahuachapán was the first geothermal field in El Salvador to be developed for commercial electricity generation (Guidos and Burgos 2012).

In 2007, LaGeo, the national electricity provider initiated a thermosolar R&D project at its geothermal plant Ahuachapán aimed at enhancing the output power of the geothermal facility.

2.1 Technical Details of the Ahuachapán Power Plant

The thermosolar-geothermal hybrid system with its prototype array of 160m^2 of parabolic mirrors has produced 0.1 kg/s of steam with 99.8% quality at 4.4 bar-g and 154°C well head conditions (Alvarenga et al. 2008).

Two solar collectors concentrate the solar irradiation into an absorber pipe (see Figure 1). The absorber pipe is filled with the Hot Temperature Fluid (HTF) Therminol 55, a thermal oil which can reach up to 290°C. It is circulated in the system at 1.5kg/s mass flow until it reaches 225°C, the minimum working temperature of the steam generator. Figure 2 displays the hydraulic circuit of the HTF.

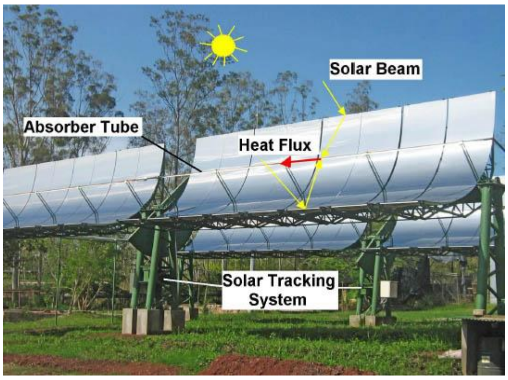

Figure 1: Solar collectors at Ahuachapán (Alvarenga et al. 2008)

Research conducted by LaGeo concluded that the appropriate scheme is to install the steam generator in the separated water line between the cyclonic separator and the flasher system (see Figure 3).

A fraction of the geothermal liquid boils in the steam generator and the generated steam can be sent to the medium pressure steam line. The residual water which does not boil is sent to the current flasher tanks. Cyclonic separation method is used to remove particulates from the steam by using rotational effects and gravity in order to separate mixtures of solids and fluids. In the flasher the liquid is flashed to steam which drives the turbine generator.

Figure 2 shows the HTF circuit. When the HTF reaches the minimum working temperature in the hot tank, both separated geothermal water and HTF are pumped to the steam generator. A mass flow of 1 kg/s of separated liquid enters the steam generator and 1.8 kg/s goes to the flasher system. A solar tracking system positions the solar collectors to the appropriate angle from 8am – 4pm.

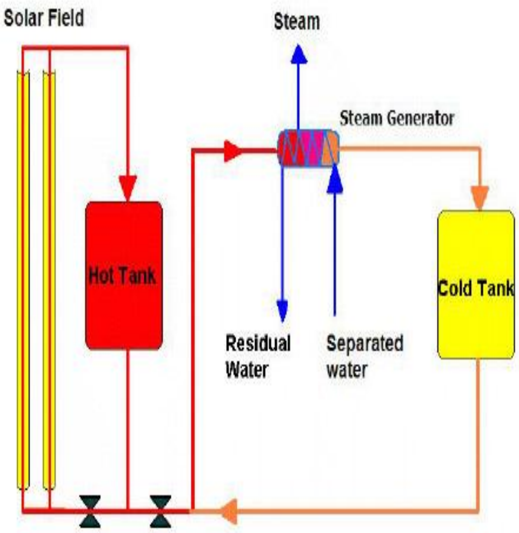

Figure 2: Hot temperature fluid hydraulic circuit (Alvarenga et al. 2008)

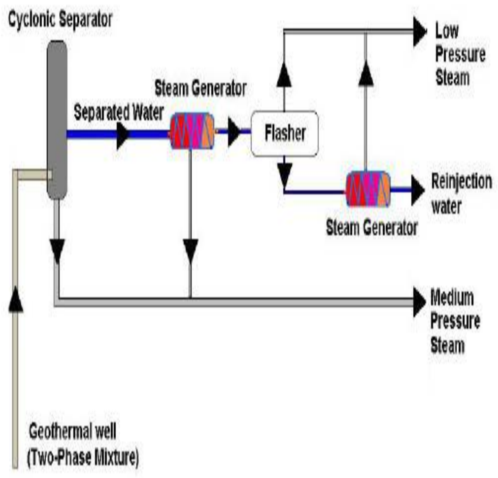

Figure 3: Circuit options for interfacing the solar and geothermal plant (Alvarenga et al. 2008)

Alvarenga et al. (2008) in their study conclude that the hybrid solar-geothermal plant could provide peak power during high-demand periods, but cannot operate as a stand-alone power plant. The authors also discovered that the temperature of the HTF (243°C) is considerably higher than that of the geothermal fluid (225°C). Due to the lower efficiency of the local solar technologies, it is recommended to import high-tech solar equipment and heat exchangers. Handal et al. (2007) in their study conclude that a combination of Concentrated Solar Power (CSP) and geothermal power facilities could present costs lower than those for hybrid solar-fossil plants. The high solar irradiation in El Salvador with almost 12 hours and global solar energy over 4.7 KWh/m^2/day is very favorable for this type of hybrid system.

3. HONEY LAKE HYBRID POWER PLANT, USA

The Honey Lake power plant is located in north-eastern California in the town of Wendel (see figures 4 and 5). The plant was built in 1989 with Greenleaf Power taking ownership in 2010 (Greenleaf Power 2012). The 35 MW plant has a long-term agreement with Pacific Gas & Electric for the power produced. The plant also utilizes the geothermal resources, making the plant a very efficient hybrid biomass-geothermal energy facility. Wood chip waste such as forest thinning, logging residue, mill waste and other waste wood is used as main fuel source. The wood generally arrives with 50% moisture content. Geothermal fluid (1,600 m depth, 118°C, 22 kg/s) is used to preheat the boiler condensate water and to dry the wood chips. Hereby, the fuel consumption is reduced and the boiler efficiency is increased. Approximately 19% of fuel is saved. Three wells are used: WEN-1, WEN-2, and WEN-3. The Honey Lake plant employs 25 staff and is indirectly responsible for an additional 85 jobs in the region.

Figure 4 and 5: Honey Lake power plant (Source: Greenleaf LLC 2012)

Electricity is generated in two cycles, a wood-geothermal cycle and a binary cycle (GeoProduction Corporation 1988).

The overall plant has the following components:

a) Power generation cycles
b) Wood-burning power cycle
c) Geothermal power cycle
d) Fuel supply and delivery processes
e) Water supply, treatment, cooling, and discharge
f) Fire protection systems
g) Power transmission lines

Project components are shown in Figure 6, the location of wells, transmission lines, etc. are shown in Figure 7. The wood-burning cycle and the geothermal power cycle are described in the following sub-sections.

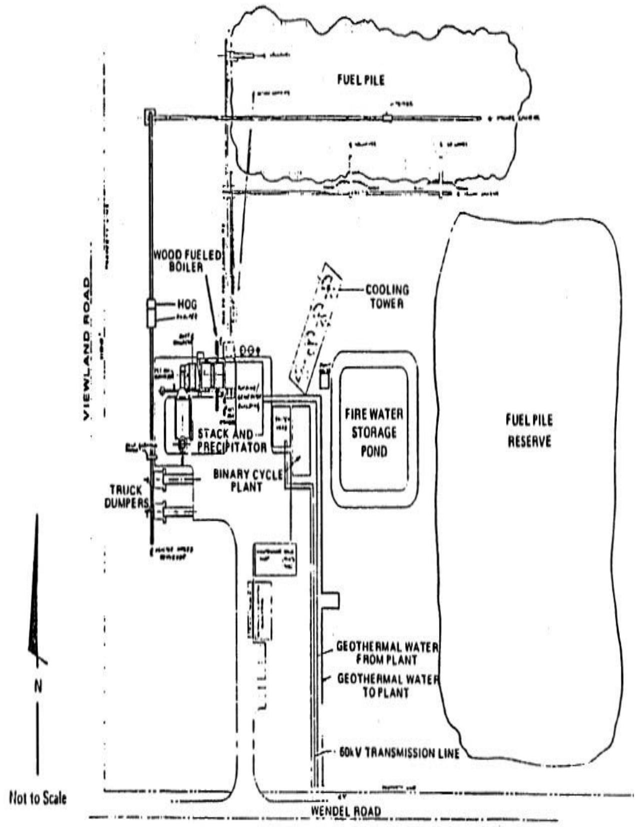

Figure 6: Honey lake power plant components (GeoProduction Corporation 1988)

3.1 The Wood-burning Power Cycle

The wood-burning power cycle employs a conventional wood-fired boiler to generate high-pressure steam. The steam boiler can provide 300,000 pounds per hour of superheated steam (950 degrees F; 1,280 pounds per square inch). This steam drives a turbine generator capable of producing approximately 34.5 MW of electricity.

3.2 The Geothermal Production Cycle

In the binary cycle geothermal fluid heats the working fluid isopropane which vaporizes at a lower temperature. Extraction steam from the wood-burning cycle turbine is condensed in a heat exchanger and used to further heat the working fluid. Once fully heated the vaporized working fluid is piped to an expander where it expands and drives a turbine generator. It has the capacity to produce 4 MW_{el}. As in other binary cycles the vaporized working fluid is then transferred to a condenser, cooled by water from the cooling tower, and returned to the geothermal heat exchangers as a liquid to repeat the process.

The total capital cost of the project was initially estimated to be USD 71,160,000 including capitalized interest during construction, fees, interconnection costs, development expenses and taxes (GeoProduct Corporation 1988).

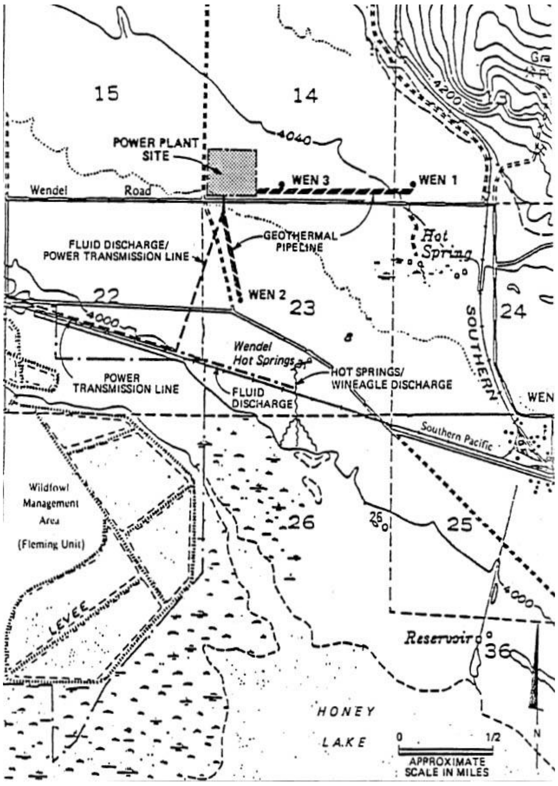

Figure 7: Honey lake site overview (GeoProduction Corporation 1988)

4. STILLWATER GEOTHERMAL-SOLAR PV HYBRID POWER PLANT, USA

The combined solar photovoltaic and geothermal power plant was built by Enel Green Power North America in the town of Fallon in Churchill County, Nevada (see Figure 8). 89,000 polycrystalline silicon solar panels complement the 47 MW geothermal plant during peak periods (Singh 2012) by adding 26 MW to the plant's output. Enel expects that around 40 million kWh of clean energy generated per year, will be enough to meet the needs of 15,000 American households as well as avoid the emission of more than 28,000 metric tons of CO_2 into the atmosphere each year (Enel Green Power 2012). This is one of the first hybrid renewable energy projects which combine the continuous generation capacity of binary cycle, medium enthalpy geothermal power with the peak capacity of solar power.

Figure 8: Stillwater Solar-Geothermal Hybrid project (Hidalgo 2012)

Considering the strengths and weaknesses of solar and geothermal technologies a joint operation would increase the effectiveness of power plants. In the last few years, solar power has grown, thanks to a quick development turn-around, relatively low up-front risk for investors and a sharp drop in the price of solar panels. Although there are high up-front geothermal development costs and associated risks, the long-term success when finding a viable underground resource, make the combination very resourceful.

Singh (2012) reports that Nevada's renewable portfolio standard target of 25% by 2025 has gone a long way in expanding the state's green sector in recent years. Northern Nevada, the center of the state's geothermal activity, already generates about 24% of its energy from renewable sources - far above the national average of 13%. The Nevada legislature has also enacted several measures for fast-tracking renewable energy development in the state.

5. INTERNATIONAL RENEWABLE ENERGY ALLIANCE (REN ALLIANCE)

The REN Alliance strives to raise awareness with respect to the combined use of renewable energy technologies. The Alliance was established in 2004 with the aim of advancing policy development, sharing information on renewables and advising international organisations, governments, decision makers and other stakeholders. The REN Alliance partners comprise international organisations representing the private sector and scientific bodies in the sectors bioenergy, geothermal, hydro, solar and wind. The International Geothermal Association (IGA) herein represents the geothermal sector.

Since its establishment the REN Alliance has conducted several side events at major events such as the COP17, the DIREC 2010, prepared sector-specific input to studies such as the ILO report on employment in the renewable energy sector or presented strategic inputs to international processes such as the installation of the Green Climate Fund. Recently, the REN Alliance partners have reinforced their collaboration with the International Renewable Energy Agency (IRENA).

6. CONCLUSION

The study shows that feasible hybrid renewable energy projects in combination with geothermal energy exist around the world and that they provide viable solutions.

A conclusion drawn from Ahuachapán is that the combination of Concentrated Solar Power (CSP) and geothermal power facilities can present significantly lower costs than those of hybrid solar-fossil plants.
As demonstrated at the Honey Lake facility also the combination of biomass and geothermal is viable, saving 19% of fuel.

Further commitment by the industry is required in addition to research on projects which focus on non-conventional energy sources. In countries with high solar radiation and favorable geothermal resources such as El Salvador it is recommended to combine these two renewable energy resources.

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