International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2019.33153

Volume 5, Issue 4
April - 2019

Review on Current Global Geothermal Energy Potentials and the Future Prospects

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ABSTRACT

This paper examined the current Global Geothermal Energy Potentials and their future Prospects. The study assessed the global geothermal energy resources, their nature, extent of availability, estimated derivable electricity, current level of exploitation, and business opportunities available. The paper presented a historical perspective of geothermal extraction for power generation, industrial process heating and cooling of buildings. In the review, different techniques for converting geothermal energy into electrical power had been studied. The paper also reported a summary of the global geothermal energy usage.

Keywords: *Geothermal, Energy Potentials, Power generation.*

1. INTRODUCTION

Energy is a critical issue for the survival of both developed and emerging economies. Globally, energy shortage remained a central bottle neck that hinders industrial and commercial developments, undermines economic growth, deters social development, and hinders overall human progress. In addressing the issues of security, increasing demand, and sustainability of energy, in recent years many countries worldwide have taken steps to increase the domestic energy security by supporting the development of their renewable energy resources including geothermal energy.

Geothermal energy is thermal energy generated and stored in the Earth and originates from the original formation of the planet, from radioactive decay of minerals, from volcanic activity, and from solar energy absorbed by the surface (Think Global Green, 2008). The geothermal gradient, which is the difference in temperature between the core of the earth and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. Geothermal energy is relatively cleaned, emission-free, renewable, solar energy derivative and economically friendly (Think Global Green, 2008).

For many centuries man has taken advantage of geothermal energy for purposes such as cooking and bathing; for example, the Romans used waters heated by the earth in bathhouses (Climate Institute, 2008). An early example of commercial geothermal energy use took place in Idaho in 1890, when the Boise Water Works Company drilled wells to create a geothermal radiant heating system for the city. Hot water from the geothermal wells was piped into more than 200 homes and businesses; this system, as well as three newer versions, is still in use today (Idaho Department of Water Resources, 2007).

Geothermal energy was first used to generate electricity in Larderello, Italy in 1904, when a turbine there lit five light bulbs (Renewable Energy UK, 2008).

Presently, the U.S. has more geothermal electric generation capacity than any other nation. According to the Geothermal Energy Association (GEA), U.S. geothermal capacity stands at 3,086 MW (Bertani, 2010). The estimate of the current worldwide geothermal electricity generating capacity is around 11,224 MW, with considerable new development under way leading to a prediction that, by 2015, worldwide capacity could be up to 18,500 MW (Jennejohn et al., 2012).

2.0 GLOBAL GEOTHERMAL ENERGY POTENTIAL

Reports examining the international status of geothermal development were published by the US Geothermal Energy Association (GEA) and the International Geothermal Association (IGA) in 2005, 2007, 2010 and 2012. For the past three decades, the geothermal power industry has been experiencing steady growth and support around the world from governments keen to find a cheap source of abundant energy (Mainwaring, 2010), and according to GEA and IGA reports, geothermal energy is seeing increasing interest from all corners of the world.

Estimate of the global geothermal electricity generating potential varies from year to year. Both the number of countries producing geothermal power and its total worldwide capacity under development appear to be increasing significantly (Holm et al., 2010).

In 2005, there were 8,933 MW of installed power capacity in 24 countries, generating 55,709 GWh per year of green power, according to the International Geothermal Association (Holm et al., 2010). IGA reports in 2010 that 10,715 MW is on line generating 67,246 GWh, with the largest capacity in the United States (3,086 MW), the Philippines (1,904 MW) and Indonesia (1,197 MW) (Bertani, 2010). This represents a 20% increase in geothermal power on line between 2005 and 2010 (Holm et al., 2010).

According to IGA, the countries with the greatest increase in installed capacity (MW) between 2005 and 2010 were: 1) US - 530 MW, 2) Indonesia - 400 MW, 3) Iceland - 373 MW, 4) New Zealand - 193 MW, and 5) Turkey 0 62 MW. In terms of the percentage increase the top five countries were 1) German - 2,774%, 2) Papua-New Guinea - 833%, 3) Australia - 633%, 4 Turkey - 308%, and 5) Iceland - 184% (Bertani, 2010).

Geothermal Energy Association (GEA) reported in 2007 there were 46 countries considering geothermal power development (Gawell and Greenberg, 2007). In 2010, GEA report identified 70 countries with projects under development or active consideration, a 52% increase since 2007 (Holm et al., 2010).

Energy reviews based on surveys for 2009, presented in combination with the World Geothermal Conference 2010, indicated that geothermal resources have been identified in over 90 countries while quantified utilization is recorded in 78 countries (Georgsson and Fridleifsson, 2010). In 2009, the worldwide use of geothermal energy was estimated to be 67 TWh/yr of electricity (Bertani, 2010), and direct use 122 TWh/yr (Lund et al., 2010).

To a broader range, the number of countries producing geothermal power has grew at a much faster pace from 18 countries in 1990 to 24 countries in 2010 representing a significantly increase of 33% while geothermal power production rose from 5,831 MW in 1990 to a total of 10,715 MW in 2010 – representing a 50% growth in geothermal power for a decade, according to Geothermal Energy Association (GEA) (Bertani, 2010).

The global geothermal power market continued to grow substantially in 2011-2012, outpacing the US geothermal market by a noticeable margin, International Geothermal Association (IGA) reported. As of May 2012, approximately 11,224 MW of installed geothermal power capacity was online globally (Jennejohn et al., 2012). IGA projects this will grow to 18,500 MW by 2015 in 35 countries, which based upon the large number of projects under consideration, appear reasonable if not conservative (Holm et al., 2010).

Projects under development grew the most dramatically in two regions of the world, Europe and Africa. Ten countries in Europe were listed as having geothermal projects under development in 2007, and in 2010 this has more than doubled to 24. Six countries in Africa were identified in 2007, and in 2010 eleven are found to be actively considering geothermal power (Holm et al., 2010).

In Asia, countries using geothermal energy include Armenia, China , Georgia, India , Iran , Nepal , Taiwan, Thailand , and Turkey while those in Pacific Islands are Australia, Fiji , Indonesia , Japan , New Zealand , Papua New Guinea, Philippines, Samoa, and Vanuatu. In Central America, Costa Rica, El Salvador, Guatemala, and Nicaragua together generated 510 MW of electricity from geothermal in 2010 (Holm et al., 2010). The North American countries using geothermal energy are Canada, Mexico, and the United States of America while in South America, Argentina, Bolivia, Chile, and Peru have Identified Projects under Consideration. In the Caribbean only Guadeloupe produced 16 MW in 2010 while Dominica, Montserrat, Netherland, Antilles (Saba), St. Kitts and Nevis have identified projects under consideration. In Africa, only approximately 217 MW of

DOI: 10.31695/IJASRE.2019.33153

geothermal resources have been developed in Kenya and Ethiopia for electricity production while Algeria, Comoros Islands, Djibouti, Madagascar, Rwanda, South Africa, Tunisia, Yemen, and Zambia have their resources under consideration (Holm et al., 2010).

Countries generating geothermal electricity in Europe are Austria, Croatia, France, Germany, Iceland, Italy , Portugal , Russia, and Spain (Canary Islands), where as Belarus, Czech Republic, Denmark, Greece, Hungary, Ireland, Latvia, Norway, Poland, Romania, Serbia , Slovakia, Switzerland , The Netherlands, and United Kingdom have identified projects under consideration (Holm et al., 2010).

In general, countries projected to Install Initial geothermal capacity by 2015 are Argentina, Canada, Chile, Greece, Honduras, Hungary, Nevis, Romania, Spain, Slovakia, and the Netherlands. While additional countries with identified projects under consideration Algeria, Armenia, Belarus, Bolivia, Comoros Islands, Croatia, Czech Republic, Dominica, Denmark, Djibouti, Fiji, Georgia, Guadeloupe, India, Iran, Ireland, Latvia, Madagascar, Montserrat, Nepal, Norway, Peru, Poland, Rwanda, Saba, Samoa, Serbia, South Africa, Switzerland, Tunisia, United Kingdom, Vanuatu, Yemen, and Zambia (Holm et al., 2010).

The growth in geothermal worldwide is currently fueled by a number of factors: economic growth, especially in developing markets; the electrification of low-income and rural communities; increasing concerns regarding energy security and its impact on economic security (Jennejohn et al., 2012).

Additionally, the majority of the growth in the development of global geothermal resources is occurring in countries with large, untapped, conventional geothermal resources. As more countries recognize and understand the economic value of their geothermal resources, their development and utilization becomes a higher priority (Jennejohn et al., 2012).

Furthermore, new technologies appear to be underpinning geothermal expansion in some regions which have already seen significant development of their conventional resources. In the US and Europe, for example, the geothermal industry is increasingly using binary technology that can utilize more moderate and low temperature resources to generate electricity (Jennejohn et al., 2012). Also, energy and economic security are compelling drivers for the adoption of policies supporting geothermal development in countries like Chile and Japan. In nearly every case, national policies are propelling growth in the strongest markets, while the current world leader – the US – appears to be growing more slowly due to policy uncertainties (Jennejohn et al., 2012). All these developmental activities indicate that geothermal energy looks set to become one of the world's major sources of sustainable, clean energy in this century (Mainwaring, 2010).

Despite these growth trends, however, the potential of geothermal resources to provide clean energy appears to be under-realized (Holm et al., 2010). In 1999, GEA prepared a report that examined geothermal power potential globally. The results of this report have shown that in the vast majority of countries the estimated potential remains undeveloped and largely untapped, even assuming the lowest projections for geothermal potential (Holm et al., 2010).

Moreover, the number of countries with geothermal power potential that are not developing their resources is still high. In fact, of the 39 countries identified in 1999 as having the potential to meet 100% of their electricity needs through domestic geothermal resources, significant power production had been developed in only nine - Costa Rica, El Salvador, Guatemala, Iceland, Indonesia, Kenya, Nicaragua, Papua New Guinea, and the Philippines (Holm et al., 2010). In East African Rift System (EARS) geothermal resources remain largely undeveloped. Currently, only approximately 217 MW of geothermal resources have been developed in Kenya and Ethiopia for electricity production. The estimated potential of geothermal resources in EARS is more than 15,000 MW (Zemedkun, 2001 as cited in Jennejohn et al., 2012).

Table 1.0: Variation in installed geothermal electricity generating capacity worldwide between 1990 and forecast in 2015 period

DOI: 10.31695/IJASRE.2019.33153

S/N	Country	1990 (MWe)	1995 (MWe)	2000 (MWe)	2005 (MWe)	2010 (MWe)	2015 Forecast (MWe)N
1.	Argentina	0	0	0	0	0	30
2.	Australia	0	0.2	0.2	0.2	1.1	40
3.	Austria	0	0	0	1.2	1.4	5
4.	Canada	0	0	0	0	0	20
5.	Chile	0	0	0	0	0	150
6.	China	19.2	28.8	29.2	28	24	60
7.	Costa Rica	0	55	142.5	163	166	200
8.	El Salvador	95	105	161	151	204	290
9.	Ethiopia	0	0	7.3	7.3	7.3	45
10.	France (Guadeloupe)	4.2	4.2	4.2	15	16	35
11.	Germany	0	0	0	0.2	6.6	15
12.	Greece	0	0	0	0	0	30
13.	Guatemala	0	0	33.4	33	52	120
14.	Honduras	0	0	0	0	0	35
15.	Hungary	0	0	0	0	0	5
16.	Iceland	44.6	50	170	202	575	800
17.	Indonesia	144.8	309.8	589.4	797	1197	3,500
18.	Italy	545	631.7	785	791	843	920
19.	Japan	214.6	413.7	546.9	535	536	535
20.	Kenya	45	45	45	129	167	530
21.	Mexico	700	753	755	953	958	1,140
22.	Nevis	0	0	0	0	0	35
23.	New Zealand	283.2	286	437	435	628	1,240
24.	Nicaragua	35	70	70	77	88	240
25.	Papua New Guinea	0	0	0	6.0	56	75
26.	The Philippines	891	1227	1909	1930	1904	2,500
27.	Portugal (The Azores)	3	5	16	16	29	60
28.	Romania	0	0	0	0	0	5
29.	Russia (Kamchatka)	11	11	23	79	82	190
30.	Spain	0	0	0	0	0	40
31.	Slovakia	0	0	0	0	0	5
32.	Thailand	0.3	0.3	0.3	0.3	0.3	1
33.	The Netherland	0	0	0	0	0	5
34.	Turkey	20.6	20	20	20	82	200
35.	USA	2774.6	2816.7	2228	2564	3087	5,400
	Total	**5,831**	**6,833**	**7,972.4**	**8,933.2**	**10,715**	**18,500**

[SOURCE: Bertani, 2010 and Holm et al., 2010].

3.0 THE WORLD'S AREAS OF MASSIVE GEOTHERMAL POTENTIAL

The distribution of the highest quality, large scale geothermal resources is generally limited to locations with a high level of tectonic activity, where the Earth's tectonic plates are interacting. These tectonically active regions are areas near plate boundaries (like Ring of Fire), continental rift zones, and mantle plumes or hot spots and are the high heat-flow (high temperature) zones where earthquakes and volcanism are concentrated. These areas are most promising for geothermal developments in the next decade, with a potential increase of geothermal power capacity from 13 GWe in 2010 to 30 GWe in 2030 (IEA, 2008)

The 'Ring of Fire' zone (include areas in southern Asian, Oceanian, Central American, North American, European and Caribbean plate boundaries like, Indonesia, Philippines, Japan, New Zealand, Italy, Mexico, Costa Rica El Salvador and the United States) which encircles the pacific ocean; is a region along which a lot of tectonic activity occurs, and the geologic conditions of this activity permit large amounts of heat to rise to Earth's surface (which occasionally results in volcanism) (IEA, 2008). Therefore, there are a limited amount of countries that can use geothermal power extensively given the current level of technology. However, research continues into how we can reduce the expense of drilling and improve the efficiency of geothermal power plants, both which will allow more areas to take advantage of this outstanding resource (Canadian Geothermal Energy Association, 2012).

DOI: 10.31695/IJASRE.2019.33153

Other areas of massive geothermal potential are continental rift zones such as Iceland and the East African Rift Valley. The East African Rift System (EARS) is comprised of the Democratic Republic of Congo, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, Tanzania, Uganda, and Zambia. The estimated potential of geothermal resources in EARS is more than 15,000 MW (Zemedkun, 2001 as cited in Jennejohn et al., 2012).

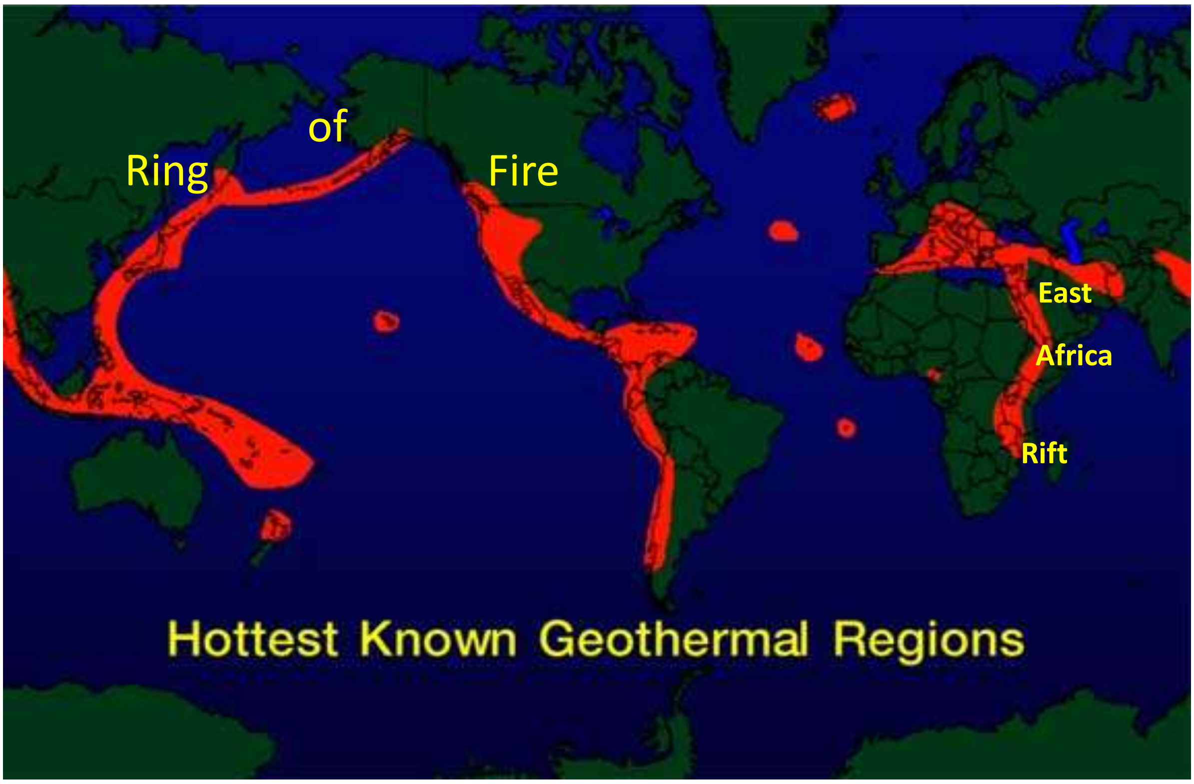

Figure 1: Hottest World's Geothermal Regions

4.0 GEOTHERMAL POWER GENERATION TECHNOLOGY

Geothermal power stations are similar to other steam turbine thermal power stations - heat from the earth's core geothermal reservoir is used to heat water or another working fluid. The vapourized working fluid is then used to turn a turbine of an electricity generator, thereby producing electricity (Renewable Energy World, 2012). The fluid is then cooled and returned to the heat source for further reheating. There are three types of geothermal power plants: the dry steam power plants, the flash steam power plants and the binary cycle power plants.

4.1 Dry steam power plants

The first, dry steam plants are the simplest and oldest design. They directly use geothermal steam of 150°C or greater to turn turbines (Fridleifsson et al., 2008). Dry steam plants operate over reservoirs that produce only steam. The steam is pushed into a tunnel called a rock-catcher, and is then funneled into the turbines, causing them to turn (Eco20-20, 2012).

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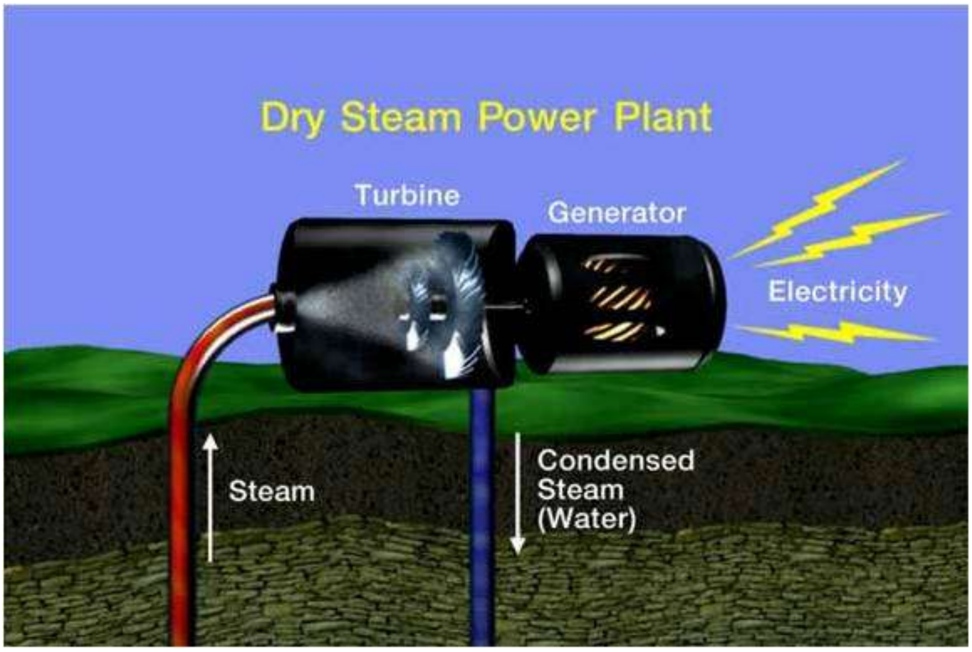

Figure 2: Dry steam power plants

4.2 Flash steam power plants

The second, flash steam geothermal power is generally associated with higher temperature geothermal sources of at least 180°C. flash steam plants pull deep, high-pressure hot water through separators into lower-pressure tanks and use the resulting flash boiled steam to drive turbines which produce the electricity (Eco20-20, 2012). This works because the pressure of the subsurface deep underground is much greater than at the Earth's surface, water can exist as a liquid at very high temperatures. The high temperature, high pressure water is brought to surface, where it is enters a low pressure chamber and 'flashes' into steam. The pressure created by this steam is channeled through a turbine, which spins to generate electrical power. Once the steam has exited the turbine, it is either released into the atmosphere as water vapour, or it cools back into liquid water and is injected back underground (Canadian Geothermal Energy Association, 2012).

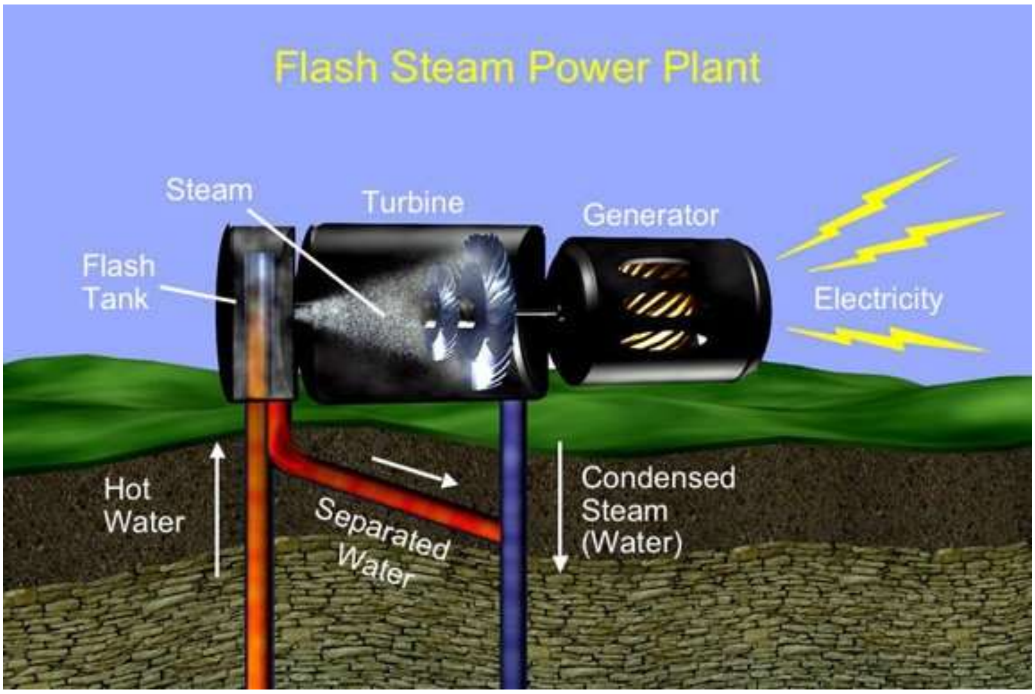

Figure 3: Flash steam power plants

DOI: 10.31695/IJASRE.2019.33153

4.3 Binary cycle power plant

The third method, the binary geothermal power, has lower temperature geothermal resources as low as 57°C (Erkan et al., 2008). Binary plants collect the heated water out of the earth, and use this heat to boil a secondary fluid with a much lower boiling point than water. When the hot geothermal water is brought to surface from deep underground, it is run through a 'heat exchanger' which transfers the heat from the geothermal water to the liquid working fluid. The reason for this is that the secondary liquid boils faster than water, and therefore takes less time to generate the steam vapour that turns the turbines (Erkan et al., 2008). This also allows for some of the lower-temperature geothermal reservoirs to be used to generate electricity. Also, there is virtually no heat or water loss because the water is moved through an entirely closed circuit. What makes a binary system unique is that it operates as a 2 closed-loops; neither the geothermal water nor the working fluid are exposed to the surface environment. All the water that is brought to surface is re-injected, and after vaporizing, the working fluid is cooled to its liquid state, so it may repeat the process. There are no-emissions in the binary geothermal cycle (Canadian Geothermal Energy Association, 2012).

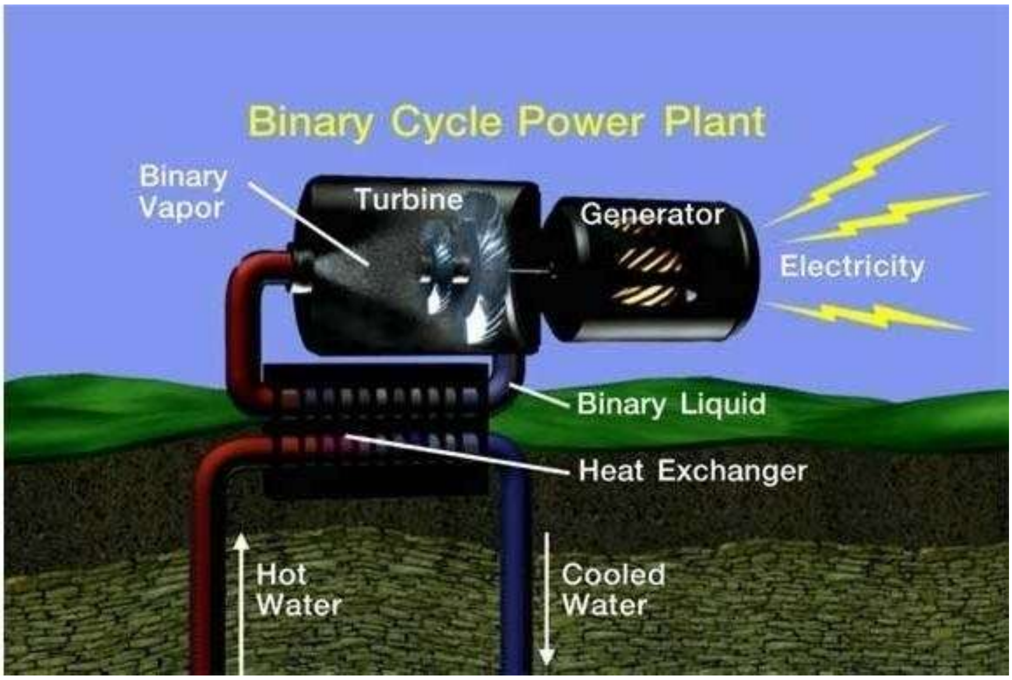

Figure 4: Binary cycle power plants

5. CONCLUSION

Geothermal energy, as a renewable source of energy, has been, and remains, a principal method for cooking, drying, heating, and electricity production in about 70 countries in the world. Currently, IGA and GEA identified around 46 countries that were considering geothermal power development with approximately 11,224 MW of installed geothermal power capacity online globally as of May 2012, and projected grow to 18,500 MW by 2015.

The study observed that recent growth in global geothermal power installations were strong in the United States (3,086 MW), the Philippines (1,904 MW) and Indonesia (1,197 MW) with projects under development grew most dramatically in two regions of the world, Europe and Africa.

Finally, the study identified three technologies currently employed in geothermal power plants: the dry steam power plants, the flash steam power plants and the binary power plants.

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