www.cenresin.org

HYDRO AND GEOTHERMAL ENERGY

Okpighe, Sunday Okerekehe,
Department of Project Management
Federal University of Technology, Owerri, Nigeria
E-mail: eloziconsultants@yahoo.com

ABSTRACT

A review of Hydro and Geothermal Energy is reported. In line with the effect of Climate Change, and the constraints imposed by these changes on mankind, the need arose for man to source for alterative and environmental friendly energy. Hydro and geothermal energies and their sources were reviewed and compared with other forms of energy globally. The economics, environmental impact and potential for the future were investigated. Consequent on the fore going, an inference was drawn that our primary attention should be focused on harnessing the solar energy for industrial and domestic usage.
Keywords: Hydropower, Geothermal Energy, Environmental Impact, Climate Change, Economics.

INTRODUCTION

Hydro Energy

According to Hydro (2010), Hydro comes from a Greek word meaning water. Hydro-electricity uses the potential energy of water stored in lakes. The potential energy in the water is turned into kinetic energy when it flows down through the pipes and into the power station. Gravity causes the down ward movement of the water. Water under pressure enters the power station and is directed onto the turbine. The kinetic energy of the moving water is turned into mechanical energy as it makes the turbine spin around. The turbine is connected via shaft to the magnets which in turn spins around inside the coils of conductor. Here the mechanical energy is turned into electrical energy ready for distribution and use.

Electricity forum (2010), said that Hydro electricity is another term for power generated by harnessing the power of moving water. Not necessarily falling water, just moving water. In the same vein, Energysavingtrust(2010), said that Hydro power systems use running water to turn a small turbine which generates electricity. The faster the water flow s and the more water there is, the more electricity can be generated. Also, Wikipedia (2010), referred to Hydroelectricity as electricity generated y hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy. Answers.com (2010), defined hydroelectricity as electricity produced from generators driven by water turbines that convert the energy in falling water to mechanical energy. In the words of Canadian Encyclopedia (2010), Hydroelectricity is obtained from the ENERGY contained in falling water; it is renewable, comparatively nonpolluting energy source and Canada's largest source of Electric Power Generation. Similarly, Darvill (2010), defined Hydroelectric power as power generated by use of energy from falling water.

TABLE 1 –DEVELOPMENTAL HISTORY OF HYDROELECTRICITY

PERIOD	LOCATION	DEVELOPMENT	COMMENTS
Mid 1770s	France	French Engineer Bernard Forest de Belidor published Architecture Hydraulique	The document described vertical and horizontal axis hydraulic machines
Late 1800s	Britain	Electric Generator was developed	Could now be coupled with hydraulics.
1878	Craigside Northumberland, England	The world's first house to be powered with hydroelectricity.	
1881	Near Niagara Falls, USA	Old Schoelkopf power station No.1 began to produce electricity.	
1882 September 30	Appleton, Wisconsin, USA	THE FIRST Edison hydroelectric power plant – the Vulcan street plant stared to produce electricity with output of 12.5kilowatts.	
1886	USA and Canada	Had about 45 hydroelectric plants	
1889	USA	Had about 200 Hydroelectric plants	
1920	USA	40% of power produced was hydroelectric.	
1933	USA	The Tennessee Valley Authority was created.	
1937	USA	The Bonneville Power Administration was created	U.S. Army Corps of Engineers involved in project development.
1928	USA	Boulder Canyon Project Act	Federal funding for large hydroelectric projects
1936	USA	Hoover Dam's 1345MW Plant	World's largest power plant
1942	USA	Grande Coulee Dam's 6809MW	Became world's largest power plant
1984	Brazil and Paraguay's	Itaipu Dam's14000MW	Became the world's largest power plant.
2008	China	Three Gorges Dam's 22500MW	Became the world's largest power plant.

2010	Norway, Democratic Republic of Congo, Paraguay and Brazil	Hydroelectric generation supply over 85% of their electricity.	
2010	USA	Has over 2000 Hydroelectric power plants.	

Source: Wikipedia (2010), http://en.wikipedia.org/wiki/hydroelectricity.

Hydroelectric Generation methods include: a) Conventional, b) Pump storage, c) Run- of-the river. d) Tide. In the words of Wikipedia (2010), Sizes and Capacities of Hydroelectric facilities are:

a) Large and specialized Industrial facilities -Generation above 10MW.
b) Small Hydro - Generating capacity up to 10MW*.
c) Micro Hydro - Generating capacity up to 100 KW
d) Pico Hydro - Generation under 5KW

*This definition could be stretched to 25MW and 30MW in Canada and USA respectively.

Small scale hydroelectricity production grew by 28% during 2008 from 2005 raising the total world small hydro capacity to 85GW. Over 70% of this was in China (65GW), followed by Japan (3.5GW), the USA (3GW) and India (2GW). According to Wikipedia (2010), the amount of available power at a hydroelectric plant is given by,

$P=\rho hgk$

(1)

Where, P = Power in Watts
ρ = Density of water (1000Kg/m3).
h = height in metres
r = the flow rate in cubic metres per second
g = acceleration due to gravity (9.81ms-2)
k = Coefficient of Turbine efficiency (ranging from 0 to 1).

ADVANTAGES AND DISADVANTAGES OF HYDRO ELECTRICITY

ADVANTAGES: a) economics, b) CO2 emission free except during manufacture and construction, c) other uses of the reservoir.

DISADVANTAGES: a) ecosystem damage and loss of land, B) flow shortage, c) methane emission(from reservoir, d) relocation and e) failure hazard.

WORLD HYDROELECTRIC CAPACITY

According to Wikipedia (2010), Brazil, Canada, Norway, Switzerland and Venezuela are the only countries in the world where the majority of the internal electric energy production is from hydroelectric power, while Paraguay not only produces 100% its electricity from hydroelectric dams, but exports 90% of its production to Brazil and to Argentina. Norway produces 98 – 99% of its electricity from hydroelectric sources (see Table 2 below).

Table 2 – Ten of the Largest Hydroelectric Producers as at 2009

Country	Annual hydroelectric production(TWh)	Installed capacity(GW)	Capacity factor	% of total capacity
China	585.2	196.79	0.37	22.25
Canada	369.5	88.974	0.59	61.12
Brazil	363.8	69.080	0.56	85.56
USA	250.6	79.511	0.42	5.74
Russia	167.0	45.000	0.42	17.64
Norway	140.5	27.528	0.49	98.25
India	115.6	33.600	0.43	15.80
Venezuela	86.8			67.17
Japan	69.2	27.229	0.37	7.21
Sweden	65.5	16.209	0.46	44.34

SOURCE: http://en.wikipedia.org/wiki/Hydroelectricity

Table 3 – Major Hydroelectric Projects over 5000MW

Name	Capacity(MW/	Country	Construction	Completion
Red Sea Dam	50,000	Africa/Middle East	proposed	
Grand Inga Dam	39,000	Congo DR	2014	2025
Three Gorges Dam	22,500	China	1994	2011
Baihetan Dam	13,050	China	2009	2015
Belo Monte Dam	11,233	Brazil	Proposed	

SOURCE: http://en.wikipedia.org/wiki/Hydroelectricity

Table 4 – World Renewable Energy Potential.

Energy Type	Energy(TW)
Solar	86,000
Wind	870
Geothermal	32
Global Consumption	15
Hydro	7.2

SOURCE: http://en.wikipedia.org/wiki/Hydroelectricity

GEOTHERMAL ENERGY

According to Wikipedia (2010)[1], Geothermal Energy has its root from the Greek words "geo" which means earth and "thermos" which means heat. Geothermal Energy therefore is energy extracted from heat stored in the earth. In the same vein, Chevron (2010), posits that Geothermal Energy is created by the heat of the earth. EIA (2010), say that Geothermal Energy is generated in the earth's core. In the words of Energy quest (2010), Geothermal Energy has been around for as long as the earth has existed. According to Wikipedia (2010) [1], this geothermal energy originates from the original formation of the planet, from radioactive decay of minerals, from volcanic activity and from solar energy absorbed at the surface.

TABLE 5 – HISTORICAL DEVELOPMENT OF GEOTHERMAL ENERGY

PERIOD	LOCATION	DEVELOPMENT
3rd Century BC	The Qin Dynasty in China's Lisan mountain at the same site where the Huaqing chi palace was later built.	The oldest known hot spring
1st Century AD	Aquae Sulis, Bath, Somerset, England	Following the Roman conquer here, the hot springs were used to feed public baths and under water heating.
14th Century	Chandes- aAigues, France	The world's oldest geothermal district heating system
1827	Larderello, Italy	Earliest industrial exploitation with the use of geyser steam to extract boric acid from volcanic mud.
1892	Boise, Idaho, USA	America's first district heating system by geothermal energy.
1900	Klamath Falls, Oregon, USA.	America's second district heating system by geothermal energy.
1904 July 4th	.Larderello dry steam field, Italy	Prince Piero Ginori Conti tested the first geothermal power generator which lit 4 bulbs.
1911	Larderello dry steam field, Italy	The world's first commercial geothermal power plant was built.\
1926	Boise, Idaho, USA	A deep geothermal well was used to heat green houses.
1926	Ice Land and Tuscany	Geysers were used to heat greenhouses.
1930	Ice Land	Charlie Lieb developed the first downhole heat exchanger to heat his house.
1943	Ice Land	Steam and hot water from geysers began to heat homes.
1946	Common Wealth Building, Portland , Oregon	J. Donald designed the first commercial geothermal heat pump to heat the Common Wealth Building
1948	Ohio State University	Professor Carl Nielson built the first residential open loop geothermal heat pump to heat his home.
1958	New Zealand	Wairakei geothermal electricity plant built. The power peaked at 173Mw in 1965. Poihipi(1996) and Ohaaki(1996/7) then followed suit.
1960	The Geysers , California, USA.	Pacific Gas and Electric began operation of the first successful geothermal Power Plant .The original turbine lasted for more than

		30years and produced 11Mw net power.
1967	USSR	The binary cycle power plant was first demonstrated.
1973	Sweden	Application of the geothermal heat pump technology.
1981	USA	The binary cycle introduced in USA.
2006	Chena hot springs, Alaska	Binary cycle plant became on-line producing electricity from a record low fluid temperature of 57^0C.

SOURCE: http://en.wikipedia.org/wiki/Geothermal_energy

According to Chevron (2010) and Wikipedia (2010) [1], Chevron is the largest producer of geothermal energy in the world. Chevron's geothermal operations are as listed in Table 6 below:

Table 6 Chevron's Geothermal Operations.

YEAR	LOCATION	DEVELOPMENT
1960s	California, USA	The Geysers
1970s	Luzon, Philippines	Tiwi and Makiling-Banahaw
1980s	Java, Indonesia	Salak and Darajat fields

SOURCE: www.chevron.com

Chevron (2010), posited that her geothermal operations from the four projects in Indonesia and the Philippines have a capacity to produce 1,273megawatts of renewable geothermal energy. Wikipedia (2010)[1], quoted the International Geothermal Association(IGA) as reporting that 10,715megawatts(MW) of geothermal power in 24 countries is online and that the IGA projects growth to 18,500MW by 2015 is expected due to the projects presently under consideration. According to Wikipedia(2010)[1], the United States led the world in geothermal electricity production with 3,086MW of installed capacity from 77 power plants and that the largest group of geothermal power plants in the world is located at the Geysers, a geothermal field in California. Also, Wikipedia(2010)[1] asserted that the Philippines is the second highest producer of geothermal energy with 1,904 MW of capacity online and that geothermal power makes up approximately 18% of the country's electricity. Wikipedia (2010)[1], further stressed that the thermal efficiency of geothermal electric plants is low, around 10 – 23%, because geothermal fluids do not reach the high temperatures of steam from boilers. In the same vein, Wikipedia (2010)[1], said that because geothermal power does not rely on variable sources of energy, unlike, for example, wind or solar, its capacity factor can be quite large – up to96% ha been demonstrated. The global average was 73% in2005. According to Wikipedia (2010)[1], low temperature in the geothermal industry means temperatures of 149^0C or less. In the words of Wikipedia(2010)[1], approximately 70 countries made use of 270Petajoules(PJ) of geothermal heating in 2004, and that direct heating is more efficient than electricity generation and also places less demanding temperature requirements on the heat resource. According to Wikipedia(2010)[1], Fluids drawn from the deep earth carry a mixture of gases, notably Carbon dioxide (CO_2), Hydrogen sulphide(H_2S), Methane (CH_4) and Ammonia(NH_3). The pollutants contribute to global warming, acid rain, and noxious smells if released. Existing geothermal electric plants emit an average of 122kilograms of CO_2 per megawatt-hour of electricity, a small fraction of the emission intensity of conventional fossil fuel plants. According to Wikipedia (2010) [1], Plant construction can adversely affect land stability. Subsidence has occurred in the Wairakei field in New Zealand and in Staufen in Breisgau, Germany. Wikipedia (2010)[1] stressed that enhanced geothermal systems can trigger earthquakes as part of hydraulic fracturing.

According to Wikipedia92010)[1], the project in Basel, Switzerland was suspended because more than 10,000 seismic events measuring up to 3.4 on the Richter Scale occurred over the first 6 days of water injection.

Table 7 - Geothermal Ecomonics

PHASE	COST PER MW OF ELECTRICAL CAPACITY	BREAK EVEN PRICE E PER KWH
Plant Construction and Well Drilling	€2.5million	€0.04 – 0.10
Enhanced Geothermal Systems Capital Cost	$4M/MW	$0.054 per KWh (in 2007)
Residential Geothermal heat pumps with capacity of 10KW are routinely installed at a cost of	$1 – 3000 per KW.	
The cost of one such direct heating system in Bavaria	Greater than €1million/MW.	

SOURCE: http://en.wikipedia.org/wiki/Geothermal_energy

MATERIALS AND METHODS

MATERIALS

According to Darvill (2010), main resources needed for Hydroelectricity are: Dam, water, turbines, generators, transformers and switchgears. According to Wikipedia(2010)[1], the enhanced geothermal system needs the following components: Reservoir; Pump house; Heat exchanger; Turbine hall; Production well; Injection well; Hot water to district heating; Porous sediments; Observation well and Crystalline bedrock.

METHODS

Darvill (2010), described the working of Hydropower Station thus: A dam is built to trap water, usually in a valley where there is an existing lake. Water is allowed to flow through tunnels in the dam, to turn turbines and thus drive generators. Notices that the dam is much thicker at the bottom than at the top, because the pressure of water increases with depth.

According to Chevron (2010), when ground water seeps below the earth's surface near a dormant volcano, the water is heated by reservoirs of molten rock, usually at depths of up to

3000meters. Wells similar to those used to produce crude oil and natural gas are drilled to recover the water. Once captured, steam and hot water are separated. The steam is cleaned and sent to the power plant. The separated water is returned to the reservoir, helping to regenerate the steam source. Chevron (2010), stressed that only a small group of sites around the globe provide the special conditions needed to generate geothermal energy. At these locations, deep fractures in the earth's crust allow the molten rock to surge close enough to the earth's surface to heat water that goes underground.

RESULTS AND DISCUSSIONS

RESULTS

Data from Tables 1, 2 and 3 reveals that the current world total power generation through Hydro supersedes that through geothermal output. Worldwide, according to Wikipedia (2010) [1], about 10,715 megawatts (MW), of geothermal power is online in 24 countries. An additional 28 gigawatts of direct geothermal heating capacity is installed for district heating, space heating, spas, industrial processes, desalination and agricultural applications.

DISCUSSIONS

From the fore going , it is evident that though hydro generation is limited by topographical features, it has a clear advantage over geothermal generation which has a much more limiting constraints and confinement to highly prone volcanic regions . For every disadvantage, there is the need, to turn the consequence to an advantage; for necessity is the mother of invention. Hence volcanic eruptions that cause havoc equally can be tapped for the good of mankind. With reference to the incidents at Basel Switzerland, it therefore calls for caution in the exploitation and harnessing of geothermal energy. Lest we end up creating fractures and weak zones on the earth core which will be tantamount to setting up a time bomb for the future generations. In the regions outside "the ring of fire", the topographical features are stable and there may not be urgent need to tamper with the equilibra if it is considered that there exist alternative sources of energy. More focus therefore should be on development of more hydro stations by emulating Paraguay. The world renewable energy potential as in Table 4 above points the way to SOLAR ENERGY as our best option as it is abundant in the universe.

CONCLUSSION

In conclusion therefore, in order for mankind to harness the much needed energy for industrial and domestic consumption, more focus should be on solar energy, followed by wind energy and hydro energy in that order. Geothermal should be least considered, exception of the rule only to those who already inhabit the region classified as "ring of fire".

ACKNOWLEDGEMENTS

Due acknowledgement is hereby made to all the authors whose works have been cited and also to the Nigerian Society of Chemical Engineers (the organizers of this conference).

REFERENCES

Answers.com(2010), Hydroelectricity: Definition from Answers.com. http://www.answers.com/topic/hydroelectricity.

Canadian Encyclopedia(2010), Hydroelectricity. http://www.thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Pa---

Chevron (2010), Geothermal Energy: Discover How Chevron Technology Creates Clean, Geothermal Energy. www.chevron.com.

Darvill (2010), Energy Resources: Hydroelectric Power. http://www.darvill.clara.net/altenergy/hydro.html

EIA (2010), EIA Energy Kids – Geothermal. www.eia.doe.gov/kids/energyfacts/sources/--/geothermal.html.

Electricityforum(2010),Hydroelectricity Explained. http://www.electricityforum.com/hydroelectricity.html.

Energyquest(2010), The Energy Story – Chapter10: Geothermal Energy. www.energyquest.ca.gov/story/chapter10.html.

Energysavingtrust(2010), Small Scale Hydro Power – Mini & Micro Hydro Power Systems – Energ---. http://www.energysavingtrust.org.uk/Generate-your-own-energy/Hydro---

Hydro(2010), Hydro Electricity. http://www.hydro.com.au/handson/students/hydrelec.html.

Wikipedia (2010), Hydroelectricity. http://en.wikipedia.org/wiki/Hydroelectricity.

Wikipedia (2010)[1], Geothermal Energy. http://en.wikipedia.org/wiki/Geothermal_energy.