

Renewable Energy: Environmental Impacts and Economic Benefits for Sustainable Development

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Abstract:- The inevitable increase in population and the economic development that must occur in many countries have implications for the environment. This is because energy generation processes (e.g., generation of electricity, heating, cooling, or motive force for transportation vehicles and other uses) are harmful and therefore pollutes the ecosystem. Energy is considered to be a key player in the generation of wealth and hence a significant component in economic development. It is central to sustainable development and poverty reduction efforts. It has positive effect on all aspects of development; social, economic, and environmental including livelihoods, access to water, agricultural productivity, health, population levels, education and gender related issues. This makes energy resources extremely significant for every country in the world. In this paper, renewable energy sources, their economic benefits for sustainable development, environmental impact including global warming, advantages and disadvantages and strategies for optimum exploitation for sustainable development are highlighted.

Keywords: Renewable energy, economic benefits, environmental impact, optimum exploitation, sustainable development

I. INTRODUCTION

Energy is central to sustainable development and poverty reduction efforts. It affects all aspects of development-social, economic, and environmental-including livelihoods, access to water, agricultural productivity, health, population levels, education, and gender related issues (Umar & Abubakar, 2014). The World Energy Committee states that there exists no risk free energy resource and for this reason, while choosing the energy resources, cost factors must be considered with environmental effects. Today, prevention of environment pollution and conservation of environment have a dimension exceeding national borders (Grigoriu, 2008). The risks that result from using of fossil fuels increasingly (petroleum, coal and gas) must be decreased. To decrease such risks and maximise energy productivity, energy resources that emit less harmful gas in the atmosphere (like Carbon-dioxide (CO₂)) must be preferred in addition to renewable energy. Otherwise, destruction of ecological balance and disasters in future will be inevitable (Keith, 2009). The negative effects of renewable energy resources on environment are lesser than the conventional energy resources. Costs of renewable energy resources are lesser than the fossil origin

fuels (Bozkurt, 2010). There are so many sources of renewable energy, however in this paper, Solar, Wind, Biomass, Hydropower and Geothermal sources of energy are highlighted.

II. SOLAR ENERGY

Solar radiation reaches the Earth's surface at a maximum flux density of about 1.0 kWm⁻² in a wavelength band between 0.3 and 2.5μm (Oji *et al.*, 2012). This is called short wave radiation which includes the visible spectrum. For inhabited areas, this flux varies from about 3 to 30 MJm⁻² day⁻¹, depending on place, time and weather (Gencoğlu, 2008). This is an energy flux of very high thermodynamic quality, from an accessible source of temperature very much greater than from conventional engineering sources. The flux can be used both thermally (e.g. for heat engines) or, more importantly, for photochemical and photo-physical processes (e.g. photovoltaic power and photosynthesis) (John & Tony, 2006). Solar energy is an energy resource that comes from the sun and varies between the values of 0-1100 W/m² on earth. Solar energy is clean, costless and limitless. Firstly, solar energy was used as heat energy but in recent years, it is also being used as an electric energy source together with developed technology (Unal, 2008). The electric energy is being obtained by means of solar panels and photovoltaic (PV) cells which decreases as the day goes by (Guney & Onat, 2008).

A. Economic Benefits for Sustainable Development

In developing nations, the PV generation system plays an important role in total electrical energy demand, and solar photovoltaic energy has gained a lot of attention because it is renewable, friendly to the environment, and flexible for installation (Guney & Onat, 2008). Solar energy is inconsumable energy resource that does not cause environment pollution. Because of the increase in fuel prices experienced in recent years, solar energy that was not considered economical few years ago, has become very economical in most areas. Solar energy, alternative to energy resources like petroleum and coal, is highly promising (Liquan & Zhixin, 2009). Buildings could be heated by either orienting them toward the sun (passive solar heating) or pumping a liquid such as water through roof top collectors (active solar heating). Several solar

thermal systems can collect and transform radiant energy from the sun into high-temperature thermal energy (heat), which can then be used directly for domestic activities or converted to electricity. These approaches are used mostly in desert areas with ample sunlight. Solar cells that convert sunlight to electricity can be incorporated into roofing materials or windows, and the expectation is that the high cost installation will fall in due course (Umar and Abubakar, 2014).

B. Solar PV: Global Status Report

The renewable energy sector employed 9.8 million people in 2016, an increase of 1.1% over 2015. By technology, solar PV and biofuels provided the largest number of jobs. Employment shifted further towards Asia, which accounted for 62% of all renewable energy jobs (not including large-scale hydropower), led by China. During 2016, at least 75

GWdc of solar PV capacity was added worldwide, equivalent to the installation of more than 31,000 solar panels every hour. More solar PV capacity was installed in 2016 (up 48% over 2015) than the cumulative world capacity five years earlier. By year's end, global solar PV capacity totalled at least 303 GW (REN21, 2017). The annual global market for solar photovoltaics (PV) increased only slightly in 2018, but enough to surpass the 100 GWi level (including on- and off-grid capacity) for the first time. Cumulative capacity increased approximately 25% to at least 505 GW; this compares to a global total of around 15 GW only a decade earlier (Fig. 1). Higher demand in emerging markets and in Europe, due largely to ongoing price reductions, compensated for a substantial market decline in China that had consequences around the world (REN21, 2019).

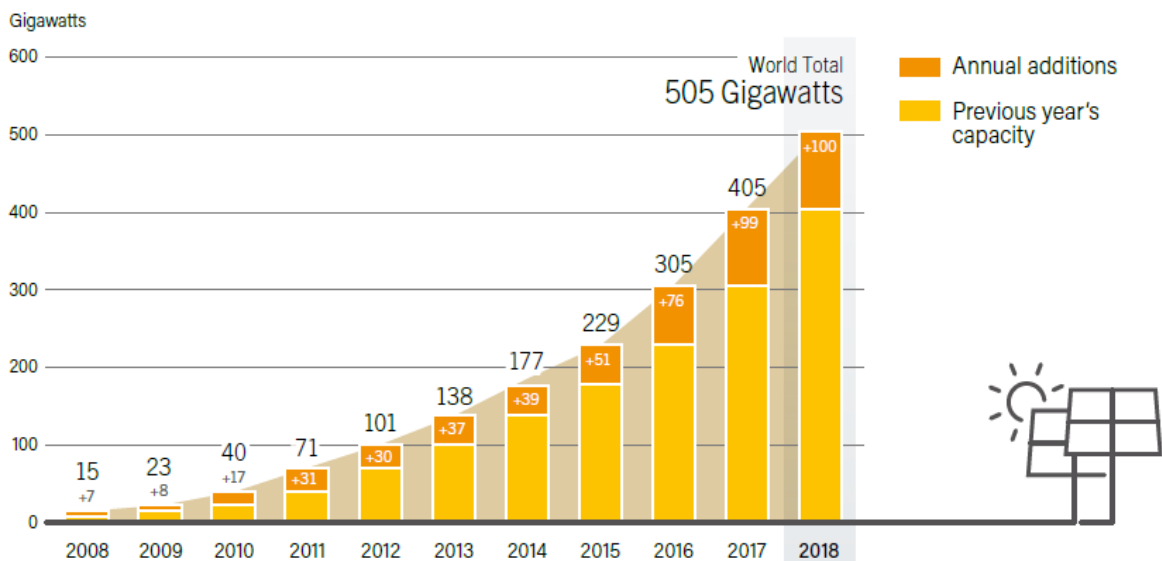


Fig. 1. Solar PV Global Capacity and Annual Additions, 2008-2018 (REN21, 2019)

C. Environmental Effects of Solar Energy

Photovoltaic is now a proven technology which is inherently safe, as opposed to some dangerous electricity generating technologies. Over its estimated life, a photovoltaic module will produce much more electricity than was used in its production. A 100 W module will prevent the emission of over two tonnes of CO₂. Photovoltaic systems make no noise and cause no pollution while in operation. PV cell technologies that have relatively lower environmental risks compared to other types of electric sources. However, chemicals used in PV cells could be released to air, surface water, and groundwater in the manufacturing facility, the installation site, and the disposal or recycling facility (Klugmann-Radziemska, 2011). The production of photovoltaic devices involves the use of variety of chemicals and materials (eg.1,1,1-trichloroethane, acetone, ammonia, isopropyl alcohol, and methanol) (California Energy Commission, 2003). Depending on their location, larger utility-scale solar facilities can raise concerns about land degradation and habitat loss and impacts from utility-scale solar systems can be minimized by sitting them at lower-quality locations

such as abandoned mining land, or existing transportation and transmission corridors (Hand, 2012).

D. Strategies for Optimum Exploitation of Solar Energy

- Setting up and maintaining a comprehensive information system on available solar energy resources and technologies.
- Providing adequate resources to Energy Commissions, to domesticate solar and other renewable energy technologies.
- Providing adequate incentive to local manufacturers for solar energy system.

E. Advantages of Solar Energy

- The energy from the Sun is free.
- The sun does not produce greenhouse gases and therefore is environmentally friendly.
- The sun will always be there during our lifetime. It does not run out.
- It prevents unnecessary and excessive commercial energy consumptions of buildings by using the natural heating and cooling systems.

- v. It meets the energy need in areas without electric network.

F. Disadvantages of Solar Energy

- i. It is relatively expensive to build solar power stations.
- ii. PV cells operate in low output.
- iii. Effect of planar collector systems may lead to dangerous situations in respect to health because of high temperatures and poisonous heat transformation fluids.
- iv. Electricity can only be produced when there is enough light.
- v. During the production of solar cells, workers expose to poisonous matters.

III. WIND ENERGY

The greater heating of the earth at the equator than at the poles and the earth's rotation set of flows of air called wind. This indirect form of solar energy can be captured by wind turbines and converted into electricity. Since 1990, wind power has been the world's fastest growing source of energy with its use increasing almost sevenfold between 1995 and 2004 (Oyedepo, 2012). Europe is leading the way into the age of wind energy. Still much of the world potentials for wind power remain untapped (Umar and Abubakar, 2014). The development of modern wind energy is an impressive example of successful policies to promote renewable energy. Global wind energy capacity has grown from a few hundred megawatts (MW) in 1990 to 48 000 MW in 2004 (Adil and Cutler, 2003). The annual growth rate between 2000 and 2004 was 28 % (Enete and Alabi, 2011).

A. Economic Benefits for Sustainable Development

Wind energy has become an affordable and reliable source of alternative, renewable energy. Continued research and development has led to consistently larger turbines, though the average size is only 2 MW. Despite the advances in

wind energy and turbine technology, wind energy remains a minor contributor to global energy (Adil & Cutler, 2003). Though, the high cost of wind turbines installation and maintenance coupled with limited output curtails wind energy's potential as a major source of renewable energy but yet, wind energy plays a vital role in electricity generation. Wind power alone already provides a significant share of electricity in some areas: for example, 14% in the U.S. State of Iowa, 40% in the northern German State of Schleswig-Holstein, and 49% in Denmark (Enete & Alabi, 2011). The wind energy is a clean energy resource that can contribute to the usual energy production as an energy resource under suitable conditions (Umar & Abubakar, 2014).

B. Wind Power: Global Status Report

It has been estimated that, until year 2017, the windmills installed capacity covers up about 10% of the planet's electrical energy needs. Almost 55 GW of wind power capacity was added during 2016, increasing the global total about 12% to nearly 487 GW. Gross additions were 14% below the record high in 2015, but they represented the second largest annual market to 2017. By the end of 2016, over 90 countries had seen commercial wind power activity, and 29 countries representing every region – had more than 1 GW in operation (REN21, 2017). The global wind power market continued to be fairly stable in 2018, with about 51 GW of capacity installed worldwide (including nearly 47 GW onshore and 4.5 GW offshore), down approximately 4% from 2017. Onshore installations accounted for all of the market decline. This was the fifth consecutive year with annual additions exceeding 50 GW, but also the third year of decline following the peak in 2015, when China alone installed more than 30 GW in advance of policy changes. As shown in Fig. 2, the additions in 2018 pushed cumulative capacity up 9% to 591 GW, with about 568.4 GW onshore and the rest operating offshore (REN21, 2019).

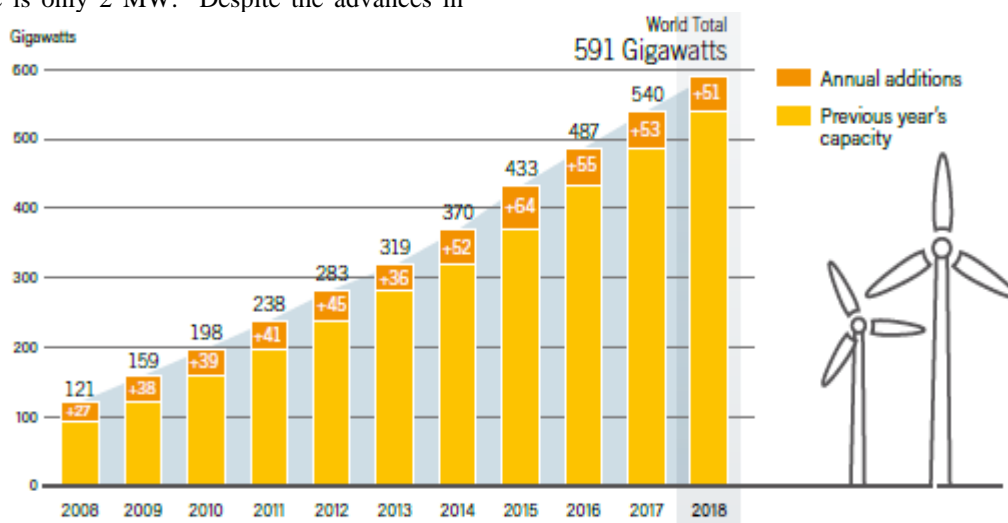


Fig. 2. Wind Power Global Capacity and Annual Additions, 2008-2018 (Paris REN21, 2019).

C. Environmental Effects of Wind Energy

A wind farm, when installed on agricultural land, has one of the lowest environmental impacts of all energy sources. It occupies less land area per kilowatt-hour (kWh) of electricity generated than any other energy conversion system, apart from rooftop solar energy, and is compatible with grazing and crops; it generates the energy used in its construction in just 3 months of operation, yet its operational lifetime is 20–25 years. Greenhouse gas emissions and air pollution produced by its construction are very tiny and declining (Ewa, 2014). However, wind energy is noisy and cause bird deaths and make parasites on radio and TV receivers. For this reason, in many European countries, mainly in England, the wind turbines are banned to be installed within boundaries of national parks or nearby to them because of their environmental effects. A 500kW wind turbine realizes the CO₂ cleaning process equal to 57000 trees (Ozyurt & Donmez, 2005). The wind energy is one of the clean energy resources and has positive effects on environment.

D. Strategies for Optimum Exploitation of Wind Energy

- i. Developing skilled manpower for provision of basic engineering infrastructure for local production of components and spare parts of wind power system.
- ii. Developing extension programmers to facilitate the general use of wind energy technology.
- iii. Providing appropriate incentive to producers, developers and consumers of wind power system.
- iv. Training skilled local craftsmen to ensure the operation and maintenance of wind energy system.

E. Advantages of Wind Energy

- i. Wind is free and will not run out
- ii. Continuous sources of energy
- iii. Clean source of energy. Wind power generation does not create greenhouse gases
- iv. Wind Energy can be used directly as mechanical energy.
- v. In remote areas, wind turbines can be used as great resource to generate energy (eg. electricity).
- vi. Land around wind turbines can be used for other uses, e.g. Farming.

E. Disadvantages of Wind Energy

- i. Windmills can be used only in areas where there is a lot of wind.
- ii. A lot of turbines are needed to make a lot of electricity.
- iii. Wind energy requires expensive storage during peak production time.
- iv. Noise pollution problem is usually associated with wind mills.
- v. Requires large open areas for setting up wind plants.
- vi. It can be a threat to wildlife. Birds do get killed or injured when they fly into turbines.

- vii. Maintenance cost of wind turbines is high as they have mechanical parts which undergo wear and tear over the time.

IV. BIOMASS ENERGY

Plant materials and animal wastes can be burned to provide heat or electricity or converted into gaseous or liquid bio-fuels. Biomass consists of plant materials (such as wood and agricultural waste) and animal wastes that can be burned directly as a solid fuel or converted into gaseous or liquid biofuels (Umar & Abubakar, 2014). Biomass is the first-ever fuel used by humankind and is also the fuel which was the mainstay of the global fuel economy till the middle of the 18th century when fossil fuels took over because they were not only more abundant and denser in their energy content, but also generated less pollution when burnt compared to biomass (Abbasi & Abbasi, 2010). In recent years, there is a resurgence of interest in biomass energy because biomass is perceived as a carbon-neutral source of energy unlike net carbon-emitting fossil fuels of which copious use has led to global warming and ocean acidification. Biomass is an indirect product of solar energy because it consists of combustible organic compounds produced by photosynthesis (Keith, 2009).

A. Economic Benefits for Sustainable Development

Burning wood and animal manure for heating and cooking, it supplies 11% of the world's energy and 30% of the energy used in developing countries. Almost 70% of the people living in developing countries heat their homes and cook their food by burning wood or charcoal. However, 2.7 billion people in these countries cannot find, or are too poor to buy, enough fuel wood to meet their needs (Abbasi & Abbasi, 2010). Bacteria and various chemical processes can convert some forms of biomass into gaseous and liquid bio fuels. Example is biogas (a mixture of 60% methane and 40% CO₂), liquid ethanol, and liquid methanol (Umar & Abubakar, 2014).

B. Bio-Power: Global Status Report

Global bio-power capacity increased an estimated 6% in 2016, to 112 GW. Generation rose 6% to 504 terawatt-hours (TWh). The leading country for electricity generation from biomass in 2016 was the United States (68 TWh), followed by China (54 TWh), Germany (52 TWh), Brazil (51 TWh), Japan (38 TWh), India and the United Kingdom (both 30 TWh) (REN21, 2017). As shown in Fig. 3, Global bio-power capacity increased an estimated 6.5% in 2018 to 130 gigawatts (GW), up from 121 GW in 2017. Total bioelectricity generation rose 9%, from 532 terawatt-hours (TWh) in 2017 to 581 TWh in 2018. The EU remained the largest generator by region, with generation growing 6% in 2018, stimulated by the Renewable Energy Directive. Other trends of previous years continued: generation grew most rapidly in China – up 14% in 2018 – and in the rest of Asia (16%), while generation in North America remained essentially stable (REN21, 2019).

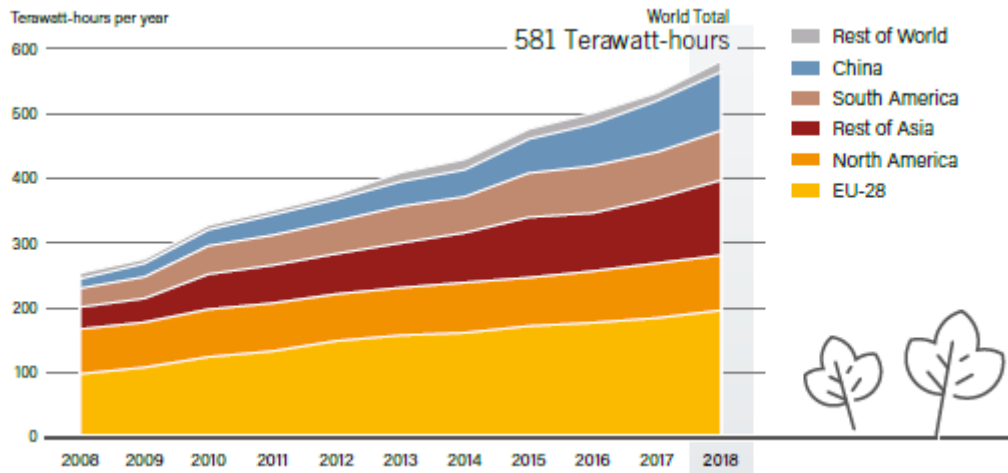


Fig. 3. Global Bioelectricity Generation, by Region, 2008-2018 (REN21, 2019)

C. Environmental Effects of Biomass

If we use biomass as a fuel, the pollutants in the form of carbon and nitrogen are increased in air which may cause air pollution and pollutants at levels higher than from traditional fuel sources such as coal or natural gas in some cases. Utilization of wood biomass, as a fuel can also produce fewer particles and other pollutants than open burning as seen in wildfires or direct heat applications. Sukhleen *et al.* (2016), stated that, according to a survey conducted, biomass is recorded as a second largest contributor to global warming. The size of biomass power plant is decided by the availability of the biomass in the nearby surrounding as the transportation plays a vital role in the economy of the plants. So it is found that railway and shipment via waterways can reduce the cost of transport which has led to a global biomass market, to build plants of 1 MW generation economically. In the process of combustion, carbon from biomass is released as carbon dioxide in atmosphere. In the dry wood, the amounts of carbon contents are approximately 50% (Umar & Abubakar, 2014).

D. Strategies for Optimum Exploitation of Biomass Energy

- i. Afforestation should be encouraged.
- ii. Development of domestic capacity in Biomass production and usage so as to reduce the health implication associated with it.

E. Advantages of Biomass Energy

- i. It's a renewable source of energy.
- ii. It's a comparatively lesser pollution generating energy.
- iii. It provides manure for the agriculture and gardens.
- iv. There is tremendous potential to generate biogas energy.
- v. Biomass energy is relatively cheaper and reliable.
- vi. Growing biomass crops use up carbon dioxide and produces oxygen.

F. Disadvantages of Biomass Energy

- i. Continuous supply of biomass is required to generate biomass energy.

- ii. Transportation of biogas through pipe over long distances is difficult.
- iii. Many easily grown grains like corn, wheat are being used to make ethanol. This can have bad consequences if too much of food crop is diverted for use as fuel.
- iv. Crops which are used to produce biogas energy are seasonal and are not available over whole year.
- v. Cost of construction of biogas plant is high, so only rich people can use it.

V. HYDROPOWER

Hydropower is electricity generated using the energy of moving water. Rain or melted snow, usually originating in hills and mountains, create streams and rivers that eventually run to the ocean. This energy has been exploited for centuries. Water flowing in rivers and streams can be trapped in reservoirs behind dams and released as needed to spin turbines and produce electricity. Solar energy evaporates water and deposits it as water and snow in other areas through the water circle. Water flowing from higher to lower elevations in rivers and streams can be controlled by dams and reservoirs and used to produce electricity (Senpınar & Gencoğlu, 2006). It is also a flexible source of electricity since the amount produced by the station can be changed up or down very quickly to adapt to changing energy demands.

A. Economic Benefits for Sustainable Development

Hydroelectricity is the term referring to electricity generated by 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, accounting for 16 percent of global electricity generation (3,427 terawatt-hours of electricity production in 2010) and is expected to increase about 3.1% each year for the next 25 years (Senpınar & Gencoğlu, 2006). Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010,

representing around 17 percent of domestic electricity use. There are now four hydroelectricity stations larger than 10 GW, the Three Gorges Dam and Xiluodu Dam in China, Itaipu Dam across the Brazil/Paraguay border, and Guri Dam in Venezuela. The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity (Askari *et al.*, 2015).

B. Hydropower: Global Status Report

More than one-third of new hydropower capacity was commissioned in China. After China, the countries adding the most capacity in 2016 were Brazil, Ecuador, Ethiopia, Vietnam, Peru, Turkey, Lao PDR, Malaysia and India. China also was the leading installer of pumped storage capability during the year, followed by South Africa,

Switzerland, Portugal and the Russian Federation (REN21, 2017). Shown in Fig. 4 is a Global utilisation of hydropower. Worldwide generation from hydropower, which varies each year with shifts in weather patterns and other local conditions, was estimated 4,210 TWh in 2018. Global pumped storage capacity (which is counted separately) increased about 1% during the year. As in many preceding years, China led in commissioning new hydropower capacity, representing more than 35% of new installations in 2018. Brazil came second, as in 2017, followed by Pakistan and Turkey, all adding more than 1 GW of capacity. Other countries that added significant capacity included Angola, Tajikistan, Ecuador, India, Norway and Canada (REN21, 2019).

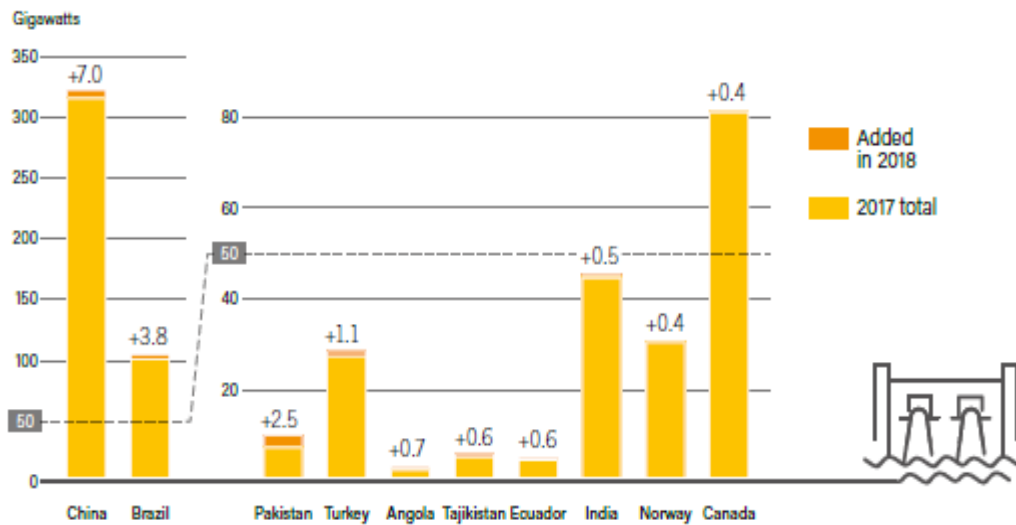


Fig. 4. Hydropower Capacity and Additions, Top 10 Countries for Capacity Added, 2018 (REN21, 2019)

C. Environmental Effects of Hydropower

The hydroelectric power plants have climatic, hydroelectric, ecological, socio-economic and cultural effects. The water collecting part of a hydroelectric power plant (reservoir) creates environmental effect when it is in operation. As the surface area of a reservoir is wider than a river and as the vaporizing increases, climatic effects occur. In this manner, humid rate in air increases, air movements change and temperature, raining and wind events differ (Unal, 2008). The hydrological effects result from flowing regime of stream and changing of physicochemical parameters. To convert rivers to reservoirs cause vaporizing of water and increasing of quantity of salt and other minerals in water. In transition from stream to lake, natural cleaning capacity decreases depending on decrease in water speed diffusion and oxygen taking capacity and the lake enters into mortification process. Blocking of migration ways both on land and in water, living areas remaining under water and annihilation of some important species cause occurring of ecological effects (Bozkurt, 2010). As a result of the expropriation made depending on size and quality of the land under water, internal and external migration events are experienced and value of land changes. However, because of the manpower movement during construction phase, the regional economy enlivens

and infrastructure services and social services cause positive effects especially in integrated projects. The barrage lake is a resource for recreation and production of water products. However, unless the natural resources and historical assets in the region are protected, cultural values may disappear (Unal, 2008).

D. Strategies for Optimum Exploitation of Hydropower

Energy

- i. Ensuring increased indigenous participation in the planning, design and construction of hydropower stations.
- ii. Providing basic engineering infrastructure for the production of hydropower plants, equipment and accessories.
- iii. Encouraging the private sector, both indigenous and foreign, in the establishment and operation of hydropower plants.

F. Advantages of Hydropower

- i. Once a dam is constructed, electricity can be produced at a constant rate.
- ii. If electricity is not needed, the sluice gates can be shut, stopping electricity generation.
- iii. The lake that forms behind the dam can be used for water sports and leisure/pleasure

- activities. Often large dams become tourist attractions in their own right.
- iv. When in use, electricity produced by dam systems do not produce greenhouse gases.
 - v. Hydroelectric energy is renewable. This means it cannot be used up.
 - vi. Flexible: As previously mentioned, adjusting water flow and output of electricity is easy. At times where power consumption is low, water flow is reduced and the magazine levels are being conserved for times when the power consumption is high.
 - vii. Hydroelectricity is much safer. There is no fuel involved.

G. Disadvantages of Hydropower

- i. Dams are extremely expensive to build.
- ii. It destroys the natural environment through flooding.
- iii. The building of dams for hydroelectric power causes a lot of water access problems.
- iv. The nearby area has to be flooded why building a dam, and this could affect nearby wildlife and plants.

VI. GEOTHERMAL ENERGY

It is defined as hot water, vapour and gases arising from the heat accumulated in various depths of the earth crust and of which temperatures are above the atmospheric temperature. The geothermal energy is the heat potential accumulated extraordinarily in accessible depths of the earth crust that can be benefited economically (Akinbami, 2001). This energy is a clean renewable energy. By aid of the energy transformation technologies, electric production is realized from hot water and vapour or they are directly used for purpose of heat energy. The waste fluid of which energy is benefited is re-injected to underground because of its negative environmental effects (Senpınar & Gencoğlu, 2006). Geothermal energy manifests in the form of heat and has its source in the earth's core, where some nuclear reactions are assumed to occur. The earth's core temperature is estimated to be ~5,000 K, and due to rock conductivity the temperature at about 4 km below the earth's surface can reach ~90 °C (Oyedepo, 2012). However, at places where geysers, hot springs, hot rocks,

or volcanoes exist, there is a much larger local potential for geothermal energy. The total estimated amount of geothermal energy is on the order of 10^{16} PJ (where 1 PJ is 10^{15} J). The geothermal heat flows from the earth's core to the surface at a rate of about 44 TW (where 1 TW is 10^{12} W), which is more than double of the world's energy consumption rate of ~15 TW. However, since this heat is too diffuse (~0.1 W/m²), it cannot be recovered unless a geographic location (i.e., geothermal site) shows a higher intensity geothermal resource. A simple calculation yields that at the consumption rate of 44 TW, the geothermal heat will be exhausted after ~ 10^{12} years (Enete & Alabi, 2011).

A. Economic Benefits for Sustainable development

This energy is a clean renewable energy and is used for electricity generation. 27% of total electric production in Philippines and 7% in California State are being covered from geothermal plants and 56MW capacity geothermal electric energy production is made in Papua New Guinea. 75% of energy need of gold mining is covered from geothermal. 86% of total heat energy (city heating) in Iceland is covered from geothermal (Senpınar & Gencoğlu, 2006).

B. Geothermal Power: Global Status Report

The countries with the largest amounts of geothermal power generating capacity at the end of 2016 were the United States (3.6 GW), the Philippines (1.9 GW), Indonesia (1.6 GW), New Zealand (1.0 GW), Mexico (0.9 GW), Italy (0.8 GW), Turkey (0.8 GW), Iceland (0.7 GW), Kenya (0.6 GW) and Japan (0.5 GW). Indonesia added about 200 MW of new capacity in 2016, ending the year with 1.64 GW. By early 2017, the country also had started commercial operations at the 110 MW Sarulla plant, one of the largest geothermal plants in the world. The plant is notable for being a combined-cycle operation, analogous to a Turkish plant coming online in 2017, where conventional flash turbines are supplemented with a binary system to extract additional energy from the post-flash turbine steam, maximising energy extraction and efficiency (REN21, 2017). At year's end, the countries with the largest amounts of geothermal power generating capacity were the United States, Indonesia, the Philippines, Turkey, New Zealand, Mexico, Italy, Iceland, Kenya and Japan (Fig. 5) (REN21, 2019).

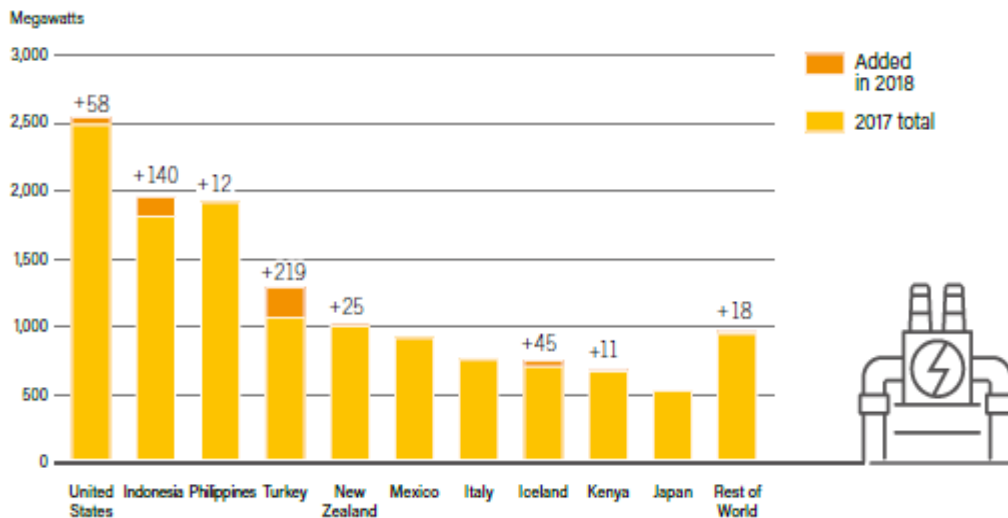


Fig. 5. Geothermal Power Capacity and Additions, Top 10 Countries, 2018 (REN21, 2019)

C. Environmental Effects of Geothermal Energy

As many countries that use geothermal energy apply reinjection, geothermal energy is considered the most positive energy resource in respect to environment. When geothermal energy is used in electric production, it comes before fossil fuels with its almost zero waste even though it is only evaluated with sulphide emissions. In geothermal power plants, azoth oxide emissions have much lower values than the power plants that use fossil fuels. For this reason, geothermal power plants are considered as a clean energy resource as they are classified risk free in respect to its effect on ozone layer and health (Senpınar & Gencoğlu, 2006).

D. Advantages of Geothermal Energy

Among the advantages of geothermal energy outlined by Ozyurt and Donmez (2005), are;

- i. It is environmentally friendly; it produces no greenhouse gasses.
- ii. It uses natural resource to heat and vaporize water.
- iii. The energy source is free and does not run out.

E. Disadvantages of Geothermal Energy

Among the disadvantages of geothermal energy outlined by Ozyurt and Donmez (2005), are;

- i. Geothermal energy requires re-injection because of emission of gases like hydrogen sulphide and carbon dioxide.
- ii. Harmful gases and minerals may occasionally come up from the ground below. These can be difficult to control (Ozyurt & Donmez, 2005).

VII. CHALLENGES AND RECOMMENDATIONS

Below are the challenges and recommendations for solution in the renewable Energy sector in Nigerian

A. Renewable Energy Challenges in Nigeria

According to Oji *et al.* (2012), some of the factors militating against the growth of the renewable energy in Nigeria include:

- i. *Financial constraints:* A basic barrier to the development of renewable energy technology in Nigeria as a developing country lies in high initial costs and long payback times.
- ii. *Technological incapability:* Though the technologies for harnessing renewable energy are being developed in Nigeria, most components have to be imported which further pushes the investment costs higher.
- iii. *Absence of a Comprehensive National Energy Policy:* There was virtually no comprehensive energy policy in Nigeria until very recently. Only sub-sectorial policies relating to energy exist.
- iv. *Low level of Public Awareness:* The level of awareness about the immense socio-economic and environmental benefits derivable from renewable energy is very low in Nigeria. The current flow of information about the development, various applications, dissemination and diffusion of Renewable energy resource and technologies is inadequate.

B. Recommendations

For effective and efficient utilization of renewable energy in Nigeria, the following recommendations will be useful.

- i. More research is encouraged into the technology and economic implications involving the initial and subsequent costs of renewable energy plants and their power efficiencies.
- ii. Government should subsidize the cost of importing Renewable Energy Technologies to bring down the high cost in Country.
- iii. Private individuals and organisations should be encouraged by appropriate authorities to invest in energy-based technologies in the country.
- iv. The wide chasm between research bodies (universities, polytechnics and research

- institutes) and manufacturing industries should be bridged.
- v. Government through appropriate agencies should create more awareness on the advantages derivable from Renewable Energy Technologies (RET).
 - vi. Government should also restrict the importation of diesel and petrol engine generators because it has adverse effects on the environment even as the global community gear towards clean (green) energies.
 - vii. Funding of energy technology researches and development initiatives in Nigerian Universities, Polytechnics and Research Institutes so as to develop renewable energy plants with increased efficiency that will be adaptable to our environment is advocated.

VIII. CONCLUSION

The nature has resources and opportunities sufficient enough to enable people live in balance without giving damage to the environment and even, to obtain comfortable life level by being industrialized. Most renewable energy sources are harmless to living things with the ability of producing a lot of energy. Although, some renewable energy plants are expensive but harnessing them can be a very big step in protecting the resources in the world and reducing greenhouse gases that affect the environment greatly. Renewable energy sources such as hydropower, biomass, geothermal, solar and wind energy should be considered and seriously supported by governments and private sectors. Sustainable energy systems are necessary to save the natural resources avoiding environmental impacts which would compromise the development of future generations.

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