THE ROLE OF RENEWABLE ENERGY SOURCES IN FUTURE ENERGY CHALLENGES

*[1]DANMALLAM I. M. AND [2]NUHU, H.

[1]Sokoto Energy Research Centre, Usmanu Danfodiyo University Sokoto
[2]School of Science and Technology, Plateau State Polytechnic, BarkinLadi, Plateau State, Nigeria.
Corresponding Author: ibrahimdanmallam@gmail.com

ABSTRACT

Currently, most of our energy supplies are based on fossil fuels, wherein the production and consumption of such finite energy sources when set side by side with the accessible reserves clearly reveal a serious future concern. Ever-increasing price of fossil fuels and global warming mediated climatic changes are associated with the intensive consumption of these fossil fuels for human comfort. In this view, the world cannot confidently rely on these finite fuel's resources. Accordingly, making of a fuel with safer, efficient, cost-effective and convincingly green (ecological affable) characteristics is the key issue towards satisfying such demands. Attempt to address the opportunities provided by renewable energy generation technologies for meeting these future challenges of energy supply by exploring renewable energy technologies such as Solar, Wind, Biomass, Geothermal and Hydro as an alternative energy supply with a great future prospect. Amongst the renewable energy sources, solar and hydro energies have been extensively explored as sustainable alternative. However, photo voltaic technologies appear promising to replace the traditional fossil fuels as well. It has been acknowledged to provide huge amount of carbon footprint free energy to the growing population. Renewable energy sources especially solar, wind and hydroelectric are the preferred choices. Thus, advancement in these renewable energy technologies are necessary to tap the true potentials of the renewable energy resources. Making use of scaling-up approach and manifold policies, it is possible to accomplish environmentally responsible, reliable and affordable energies that would definitely make the Earth greener.

Keywords: Fossil fuel, Renewable energy, Energy crisis

INTRODUCTION

Energy demand is ever-escalating since human civilization. Energy is primarily a significant factor to decide our lives standard. At this time, we are absolutely reliant on the plentiful and uninterrupted energy supply for livelihood and work. Certainly, energy became a key component in every spheres of modern economy. In this regard, one of the most frequently raised issues in the 21st century worldwide is: can we satisfy the enormous energy demand in an environmental responsive, reliable, affordable and efficient way. Since ancient times human used to obtain the energy using muscles power of animals or running water.

Meanwhile, the discovery of fossil fuels brought new revolution and marked it as the prioritized energy resource. Despite the accessibility of assorted energy resources, fossil fuels the most polluting energy resource remain principally ubiquitous. Mounting environmental alarms and energy demand enforced to search for sustainable energy resources alternative to fossil fuels (Sharma & Ghoshal, 2015).

GLOBAL WARMING PERSPECTIVES

Nowadays, there is massive awareness that Earth is in danger due to manmade pollution, over-population, and excessive utilization of non-RE resources. Thus, the threatening word so called *global warming* has been coined (Abdeen, 2012). Now, scientists, policy-makers, and environmentalists collectively are trying to inhibit the causes of global warming (GW). Undoubtedly, this paradigm called GW is bound to affect both living and nonliving systems on Earth including human, climate, animals, plants, forests, atmosphere, ground water, and oceans(Grübler et al., 1995). Let's clarify what actually happens when we refer to GW. In this regard, two relevant questions have been raised such as why and how is the Earth heating up and why it might not be a good thing for our future living.

Models of Future Energy Mix

There are variables that will determine the energy crises in the future which will likely unfold if precise action are not taken (Grübler et al., 1995; Nakicenovic, 2000). So many policies have been developed by many countries and non-governmental organizations on renewable energy application for the future (Audus, 2000). Each renewable energy source will be determined by cost and effectiveness, the cost of generating the type of energy and how effective it is are given priority.

Expenses of Fossil Fuel

Considering the cost and pollution effect of fossil fuel, of which 11 cents per kilowatt-hour bills is added to cater for carbon credit, green energy will be more cost effective (Drew, 2015).

Green Energy Technologies

Technological advancements in energy conversion from solar and geothermal energy , from the ecosystem has enormous benefits due to low rate of usage in comparison with the cycles (Sørensen, 2000; Turkenburg, 2000). This will lead to a diversified mix of sources to avert future energy crises associated with cost and over reliance on countries with fossil fuel. Renewables have little or no carbon foot print as such they have less health hazard. Green energy is available for off-grid use in small communities thereby contributing energy sources for remote areas which can substitute fossil fuel for other use and sustain local economy by job creation. They are environmentally friendly because of carbon dioxide neutrality which do not emit greenhouse gases (Freris & Infield, 2008.; IEA-ETP, 2017). Figure 1 displays cost (USD/kWh) of Renewable energy types in the USA for 2010 and 2015, which indicates that the solar thermal cost more to generate, while the Hydropower cost less to generate for both years respectively.

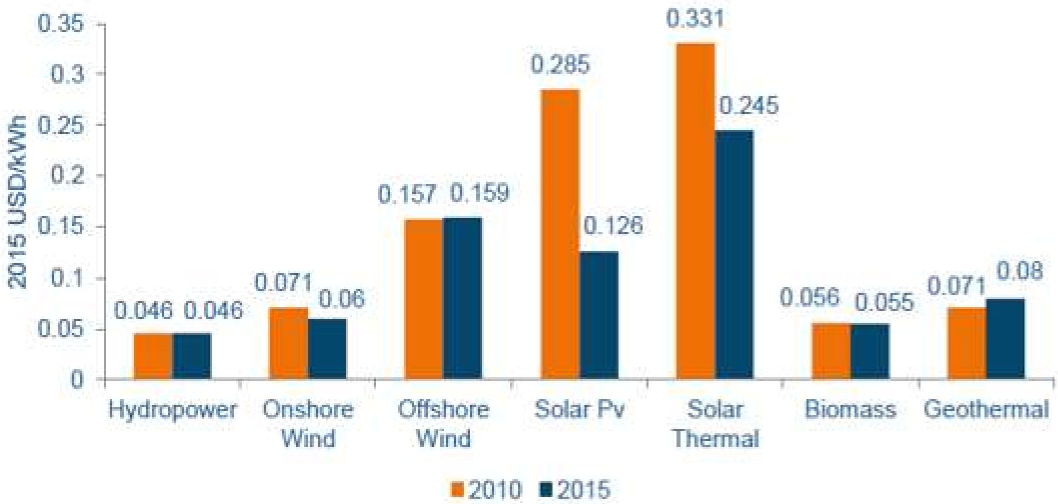

Figure 1: Cost comparison of Renewable energy types in USD/kWh in the USA for 2010 and 2015.

Table 1: Global electricity production (%) percentage using renewable sources (adapted from statistical energy year book 2016).

Regions	RE use in 2005 (%)	RE use in 2010 (%)	RE use in 2015 (%)
Pacific	18	19	25
North America	24	26	28
Middle East	4	2	2
Latin America	59	58	52
Europe	20	26	34
Communist Independent States (CIS)	18	17	16
Asia	14	16	20
Africa	17	17	19

Table 1 depicts the global electricity production percentage using RE sources in every five years interval starting from 2005 till 2015. Until now, the price of fossil fuels (with well-known pollution level) remains cheaper despite the addition of 11 USD/kWh bills to cater for carbon credit green energy (Drew, 2015). Therefore, the prices of renewable energies are the main limitations to penetrate the marketplace as of now.

Sunshine Energy

Global installed capacity of solar energy exponentially grew to 227 GWe in 2015. With about 1% of electricity which is used globally. Although countries with limited sunshine hours have most of the solar energy systems, countries with more sunshine hours and high Solar intensity have less solar systems. China is leading in world solar PV installation followed by Germany (IRENA, 2016). Reliable solar radiation data has been a challenge. Solar radiation is the basic renewable energy source in nature. It's the source of Energy to the universe which affects the global climate. Radiation data is crucial in providing modelling solar energy devices and accurate information for energy planners, engineers, and agricultural (Barabaro, Coppoliono, Leone, & Sinagra, 1978; Duffie & Beckman, 1980; Sivkov, 1964).

Solar Thermal

Solar thermal energy technologies rely solely on sunshine (Klaus et al., 2016). Solar thermal utilizes the heat from sunshine for solar heating and cooling purposes wherein the produced steam can be used to drive turbines for electricity generation. Solar collectors use fluid for thermal energy transfer. Solar thermal capacity due to its abundant and free nature has generated renewed interests in the RE domain. Repeated estimates disclosed that the future of solar thermal technologies is greatly prospective for domestic and industrial applications. Thus, much investigation is needed in order to provide systems that can function in the non-insolation period (night and non-sunshine hours) where the heat can be preserved for future usage. Significant work should be done in other to provide systems that can function in non-insolation period (night and non-sunshine hours) where the heat can be preserved for future use (Farouki, 1986; IRENA, 2016).

Solar Photovoltaic (PV)

Solar PV directly converts sunshine into electrical energy which requires battery bank to serve as storage to operate in non-insolation period. These PV systems can be used diversely for lighting, refrigeration, water pumping, irrigation, and communication network (IRENA, 2016).
Performance (efficiency) of solar cells or modules are majorly characterized by parameters such as maximum power, current density, circuit voltages and fill factor which are obtained from current-voltage characteristics. Cost of solar cells production is steadily reducing and paving the way for grid parity to be attained providing market where solar industry would strive and open new frontiers for developing nations. The cost reduction is enhanced by new PV technologies with increased efficiency and regulatory incentives to limit environmental effects. Besides, the developed solar modules have long lifespan and can effectively be recycled after disposing (IRENA, 2016).

Concentrated Solar Power (CSP)

Mirrors are used to focus solar radiation on evacuative tube collectors containing fluid its referred to as concentrated power. The notion of *concentrated solar power* (CSP) has provided further impetus in the PV technologies where mirrors are used to focus solar radiation on evacuative tube collectors containing fluid. In this configuration, the absorber chillers operate using the working fluid that drives the refrigeration process. Regarding Green House Gases (GHG) emission reduction, these chillers are much superior compared to chlorofluorocarbons used in conventional refrigerants. Absorber chillers operates using the working fluid which drives refrigeration process. Chillers reduce GHG emission in comparison to chlorofluorocarbons used in conventional refrigerants.

Wind

Wind power arises due the atmospheric movement triggered by temperature differences at the surface of Earth when ignited by solar radiation. Wind energy can be utilized to produce electricity and pump water, wherein wide-ranging coverage of surface area is prerequisite to generate substantial quantity of usable power. Hydroelectric energy exploits the gravitational potential of sunlight assisted water lifting from the oceans in elevated locations (EWEA, 2003; Gregory, 2005; IHA, 2003; Prabir, 2013).

It is well-known that wind energy is site specific and a potential RE source. In the year 2016, the global wind energy generation was estimated to be around 500 GW which was about 8% of the total power generation capacity (480 GW onshore and 20 GW offshore). Wind energy can provide 12-15% of electricity globally (EWEA, 2003). Presently the wind energy generating capacity is about 950 TWh representing 4% of power generation globally. In Denmark, 40% of electricity is generated by wind turbines the largest producer among all nations followed by Germany (15%). Entire European nations account for over 95% of wind power installations (≈10936 MW) (Gregory, 2005).

Biomass

Globally, biomass is the fourth largest most consumed energy resource, totaling about 14% of the primary energy. Biomass can effectively be used with little or without net emission of CO_2 wherein crops return the same amount of CO_2 consumed to balance the ecosystem. Using photosynthesis process, plants produce carbohydrates from CO_2 and water intake in the presence of sunlight. These stored carbohydrates are the basic biochemical for biomass production where sunshine is the primary RE energy source for photosynthesis. This cycle being renewable in the ecosystem provides high benefits to the ecological balance (Hall, Rosillo-Calle, & Groot, 1992). Efficient utilization of biomass resources has the capacity to satisfy the demand of fossil fuel with only 7% production (Wereko-Brobby & Hagan, 1996). Global production of land-based biomass ranges within 5 to 30%, where the estimated biomass energy is ≈55 EJ/yr. Biomass energy that is used for the transportations as well as power generation can exist in the three phases such as solid, liquid and gas. The highest percentage of biomass is utilized in the RE mixture. Actually, developed nations encourage the blending of biomass energy with fossil foil (called bio-ethanol and bio-diesel) for transportation. Even though the primary energy supply by fuel wood is ≈90%, measures must be taken to improve the conservative energy consumption to efficient utilization method. In this way, the amount of global charcoal consumption (≈52 MT per year) for cooking and diverse metal ores smelting can drastically be reduced (IRENA, 2016).

Generally, biomass energy is converted to heat, biogas, bio-ethanol, or electricity using various methods such as direct combustion processes (co-firing and pyrolysis) and anaerobic digestion. In the direct conversion method, carbon feedstock is used to initiate the chemical reaction. Complete burning of a kmol carbon releases an amount of heat ≈394 MJ accompanied by CO_2 (Prabir, 2013). Direct combustion of biomass can be classified into two categories for generating heat or steam directly. Using co-firing of fossil fuel biomass and coal are blended in a furnace via a traditional coal-fired steam cycle used in electric power plant. Currently, it is one of the easiest modes of biomass utilization instead of fossil fuels which does not require new investment or sophisticated technologies. Cheaper and readily available biomass from massive agricultural waste and forestry product can be processed in plants. Due to intense emission of sulfur, CO_2 and other GHGs by fossil fuel power plant it is essential to save our environment by adopting efficient bio-energies. It has been shown that co-firing can diminish the emission of various GHGs (Kurchania, Panwar, & Pagar, 2010).

Typically, the thermo-chemical decomposition (without oxygen) of organic materials at high temperatures (430 °C) takes place at lower pressure. Organic substances undergo pyrolysis resulting in fluid products (gas and liquid) with solid residue enriched with carbon content (Bini, Di Prima, & Guercio, 2010). Carbonization refers to extreme pyrolysis with mostly carbon as its residue (Ayhan, 2005). In the pyrolysis process, the heavier hydrocarbon molecules of biomass are broken down into smaller hydrocarbons together with no condensable gases including CO, CO_2 and solid carbon called char (Prabir, 2013). In the anaerobic digestion process, microorganisms are broken down into biodegradable materials without oxygen in a series of steps. This procedure is utilized in both industrial and domestic application for wastes management and energy release. Anaerobic digestion involves 4 significant biological and chemical steps such as hydrolysis, acidogenesis, acetogenesis and methanogenesis. Following such technologies GHGs emission can remarkably be reduced via the replacement of fossil fuels. This in turn reduces or eliminates the carbon energy footprint of waste treatment plants, emission of methane from landfills, industrial production of chemical fertilizers, movements of vehicle and transportation losses of electrical grids (Kurchania et al., 2010).

Bio-diesel is derived from vegetable oil and animal fat containing alkyl esters (methyl, propyl or ethyl) with long-chains. It consists of hydro-treated vegetable oil (HVO), animal fat (tallow) with alcohols that are chemically reacting lipids. It is designed for the use in regular diesel engines, thereby making bio-diesel distinctive from the vegetable and waste oils utilized in converted diesel engines (IEA, 2017). Bio-diesel and conventional hydrocarbon-based blended products are available in the retail diesel fuel market. Usually, the term ''B'' factor that indicates the quantity of biodiesel in a fuel mix are symbolized as 100% bio-diesel (B100), 20% bio-diesel (B20), 5% bio-diesel (B5) and 2% bio-diesel (B2). The Modern bioenergy growth by sector is depicted in figure 2.

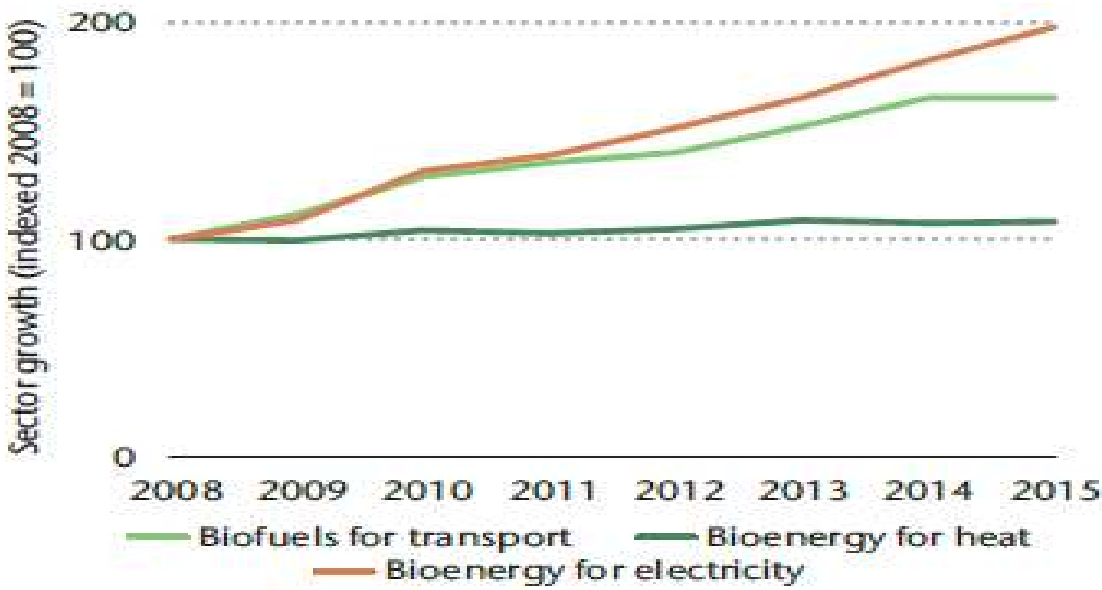

Figure 2: Modern bioenergy growth by sector, 2008-2018.
Sources: IEA (2017d), *World Energy Statistics and Balances 2017*, www.iea.org/statistics/; IEA (2017c), *Market Report Series: Renewables 2017*; IEA (2017e), *World Energy Outlook 2017*.

Geothermal

Recent progress in the modular generation of geothermal power particularly for space heating has expanded the utilization of geothermal technology (William, 2010). Heat is a significant factor of matter wherein the earth crust contributes majorly in the geothermal heat production. Currently, power output from geothermal energy contributes almost 80 TWH *(Dye, 2012)*. Moreover, by efficiently harnessing the geothermal potential it is possible to achieve over 45 EJ which is 4 times higher than the basic global consumption (contributes to below 2% of the energy output). Recently, the installed capacity is augmented to about 14 GW (IRENA, 2016). Turkey has the maximum number of geothermal installations (IRENA, 2016). They not only generate power but also store the energy on a broad array of spectral conditions. For efficient exploration of geothermal power several strategies have been adopted. Looking back, it has been exciting years for geothermal energy globally where numerous achievements were recorded and a focus for bright future prospect. However, to meet set development goals, huge financial investments and serious policy commitments should be directed for future goals of this renewable energy source (Huber & Arslan, 2012).

Hydropower

The concept of hydropower electricity generation is based on the magnets rotated within copper coils by moving water (kinetic energy). In this process, shafts in a turbine are rotated to convert the kinetic energy change into electricity by turning the rotors. Impulse and reaction types of turbines are used, where a site-specific turbine is selected after complete estimate of the operation cost. In reaction turbine, wheels are completely submerged in water to reduce the turbulence significantly. The size of dam and flow of water determines the power to be generated, in which the turbine size is chosen based on the water pressure that drives the turbine (Version2, 2016).

Despite the underutilization of hydropower, it is globally the leading RE source for electricity generation accounting ≈71% in the year 2015 with an average potential of 10000 TWh/y. A significant surge in hydropower generation (over 32%) was recorded between the year 2007 and 2015, accounting to ≈1209 GW in 2015 with an annual increase of 4%. Hydropower development is rapid in the evolving markets. It offers clean energy and water services, energy security, regional cooperation, and economic growth. Like all other RE technologies, hydropower technology development suffers from various limitations such as enhanced capacity of turbine (1000 MW turbine in the pipeline). Advanced hydropower technologies are needed to enable the renewable hybrids where both conventional and pumped storage hydropower can increasingly be utilized as a sources flexible resource to balance renewable variability (Criqui, 1996).

There is serious technological advancement in hydropower which include the following: Increasing the capacity of turbines (1000 MW turbine in the pipeline, advanced hydropower technologies that enables renewable hybrids, both conventional as well as pumped storage hydropower that is increasingly utilized as a sources flexible resource to balance variable renewable. A greater part of the new developments in hydropower is found in China, South America as well as Africa. The highest untapped hydropower potential which is about 7195TWh/y is found in Asia, which makes it to likely be the leading market of the future. China alone is responsible for 26%, while US has 9%, Brazil 8% and then followed by Canada with 7%. Table 2 displays the top hydro capacity of some countries as at 2015.

Hydro energy plays an important role in averting future energy crises as a clean renewable energy source for vital human needs. The rating of hydropower stations is based on their production capacity. For the micro hydropower it ranges (0 < 100kW), while for the mini hydro it is from (100-500 kW), for small hydropower it is from (500 kW-5 MW), and for the big hydro it is (>5 MW) (IHA, 2003). Current global installed capacity stands at about 1500 GW with more being built in developing countries. The recent production of hydropower stands around 18% with a feasible potential of 32%.The potential of hydro power energy is bright in stemming the future crises (IHA, 2003).

Table 2: Top hydrocapacity of some countries as at 2015 (IRENA 2015).

Continents	Africa	Asia	Australia& Oceania	Europe	North & Central America	South America
Gross theoretical hydropower potential (GWhy^{-1})	4×10^6	19.4×10^6	59.4×10^6	3.2×10^6	6×10^6	6.2×10^6
Technically feasible hydropower potential (GWhy^{-1})	1.75×10^6	6.8×10^6	2×10^6	10^6	1.66×10^6	2.7×10^6
Economically feasible hydropower potential (GWhy^{-1})	1.1×10^5	3.6×10^6	90×10^4	79×10^4	10^6	1.6×10^6
Installed hydropower capacity (MW)	21×10^3	24.5×10^4	13.3×10^4	17.7×10^4	15.8×10^4	11.4×10^4
Production by hydropower plants in 2002 or average (GWhy^{-1})	83.4×10^3	80×10^4	43×10^3	568×10^3	694×10^3	55×10^4
Hydropower capacity under construction (MW)	>3024	$>72.7\times10^3$	>177	$>23\times10^2$	58×10^2	$>17\times10^3$
Planned hydropower capacity (MW)	77.5×10^3	$>17.5\times10^4$	>647	$>10^3$	$>15\times10^3$	$>59\times10^3$

CONCLUSION

Ever-increasing man-made air pollution, global warming and climate change, land usage, deforestation, clean ground water depletion, and noise level have gradually been making the Earth truly unsustainable. On top, the local air pollution from road transport worldwide became distressing issue for urban air quality. Lofty GHGs emissions, energy crises, rapid depletion of clean water and fossil fuels consumption are a major concern in this century. Resolving the global demand of increasing carbon-free energy generation and environmental sustenance (greener earth) are the primary issues. The decay in the Earth's greenery, natural resources, human health quality and safety-imposed mankind to explore some unconventional energy sources to fulfil the growing need. Accordingly, renewable energy sources being inexpensive, environmentally friendly, clean (zero carbon footprint), and sustainable have emerged as suitable alternative to the conventional energy sources including polluting fossil fuels. Amongst all RE sources, solar and hydro energies have been enormously explored as sustainable alternative. Meanwhile, PV technologies appeared promising to replace the traditional fossil fuels. It has been emphasized to provide huge amount of carbon footprint free energy to the growing population, RE sources especially solar, wind and hydroelectric are the only choices. Thus, advancement in the RE technologies are necessary to tap the true potential of RE resources. Using scaling-up approach and manifold policies it is possible to accomplish environmentally responsible, reliable and affordable energies that would definitely make the Earth greener. Environmental issues will continue to grow and awareness needs to be developed. Renewable energy dependence is the only solution to stabilize the Earth and make it greener. Future carbon free energy will be predominantly driven by solar, wind and hydro-electric power. Each day more solar energy that falls on the Earth than the total amount of energy consumes by ≈7.0 billion inhabitants in 27 years needs proper exploitation. Generating energy of 30 TW by reducing 75% greenhouse gas emission by 2050 will remain an open challenge. Renewable energies being the probable solution to the global energy crises need immense investment, many scientific breakthroughs and general awareness. Several global initiatives need to be undertaken to assure the sustainability of Earth by resolving the ongoing energy crises, wherein the notion of greener manufacturing and hybrid technologies must be promoted.

REFERENCES

Abdeen, M. O. (2012). The energy crisis, the role of renewable and global warming. *Journal of Environment Management and Public Safety, 1* (1), 038-070.

Audus, H. (2000). The treatment of technology development in energy models. *Int. J. Global Energy 13*(1-3), 58-68.

Ayhan, D. (2005). Thermochemical conversion of biomass to liquid products in the aqueous medium. *Energy Source, 27*(13), 1235–1243.

Barabaro, S., Coppoliono, S., Leone, C., & Sinagra, E. (1978). Global solar radiation in Italy. *Solar Energy, 20*, 431-438.

Bini, R., Di Prima, M., & Guercio, A. (2010). Organic Rankine Cycle (ORC) in Biomass Plants: An Overview on Different Applications. *Turboden SrL, Brescia, Italy*.

Criqui, P. (1996). International markets and energy prices, the POLES model, In: Models for energy policy." Eds: J.B. Lesourd, J. Percebois and F. Valette. London, New York, Routledge. pp: 253 (214- 259).

Drew, T. S. (2015). The social cost of atmospheric releases. *Climate change Journal, 130* (2), 313 -326.

Duffie, J. A., & Beckman, W. A. (1980). Solar Engineering of Thermal Processes. New York: J. Wiley and Sons.

Dye, S. T. (2012). Geoneutrinos and the radioactive power of the Earth *Reviews of Geophysics., 50*(3), 3600-3607.

EWEA. (2003). Wind force 12. A Blueprint to achieve 12% of the worlds electricity from wind power by 2020 *Brussels Belgium*.

Farouki, O. T. (1986). Thermal properties of soils, Series on Rock and Soil Mechanics Vol. 11, Trans Tech Publications, New York.

Freris, L., & Infield, D. (2008.). Renewable Energy in Power Systems (John

Wiley & Sons Inc, Chichester, United Kingdom.

Gregory, R. G. (2005). The Industrial Windmill in Britain. Phillimore publishers, Amsterdam Netherland.

Grübler, A. M., Jefferson, A., McDonald, S., Messner, N., Nakicenovic, H.-H., & Gogner, L. S. (1995). Global Energy Perspectives to 2050 and Beyond. *World Energy Council Vienna Austria.*

Hall, D. O., Rosillo-Calle, F., & Groot, P. (1992). Biomass energy: lessons from case studies in India.

Huber, H., & Arslan, U. (2012). Geothermal Field tests with Groundwater Flow, Proceedings Thirty- Seventh Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 30 - February 1, 2012.

IEA-ETP. (2017). Report summary: Energy Technology Perspectives (2017) IEA Energy Technology perspective IEA New York , www.iea.org/sperspective/ (accessed 25/12/ 2018).

IEA. (2017). International Energy Agency (IEA) Energy Prices and Taxes (database), OECD/IEA, Paris, www.iea.org/statistics/ (accessed 28/12/ 2017).

IHA. (2003). World Atlas & Industry Guide *The International Journal Hydropower & Dams,United Kingdom, 1*(1), 1-67

IRENA. (2016). Renewable Energy statistics Yearbook (http://resourceirena.irena.org) Abu Dhabi UAE (accessed 15/5/ 2017).

Klaus, J., Olindo, I., Arno, H. M. S., René, A. C. M. M., Van, S., & Miro, Z. (2016). Solar Energy: Fundamentals, Technology and Systems UIT Cambrige United Kingdom.

Kurchania, A. K., Panwar, N. L., & Pagar, S. D. (2010). Design and performance evaluation of biogas stove for community cooking application. *Int J Sustain Energy 29*(2), 116–123.

Nakicenovic, N. (2000). Special Report on Emission Scenarios. *Cambridge University Press United Kingdom.*

Prabir, B. (2013). Biomass Gasification, Pyrolisis and Torrefaction: Practical Design and theory. *Second edition. Academic press London UK*, 45-47.

Sharma, S., & Ghoshal, S. K. (2015). Hydrogen The Future Transportation Fuel: From Production to Applications. *Renewable and Sustainable Energy Reviews, 43*(1151).

Sivkov, S. I. (1964). On the computation of the possible and relative duration of sunshine. Transitional and Main Geography Observation 160 paragon press New York U.S.A.

Sørensen, B. (2000). *Renewable Energy* (2nd ed.). Copenhagen AcademicPress.

Turkenburg, W. C. (2000). Renewable energy technologies, In: World Energy Assessment, Ed: J. Goldemberg, Washington D.C., UNDP. 220 - 272.

Version2, C. E. (2016). Hydropower engineering Module 5. Indian institute of Technology(IIT), Kaharagpur. www.academia.edu (accessed on 29/12/2017).

Wereko-Brobby, C. Y., & Hagan, E. B. (1996). Biomass conversion and technology. Wiley, New York.

William, E. G. (2010). Geothermal Energy: Renewable Energy and the Environment.Taylor &Francis Publishers.