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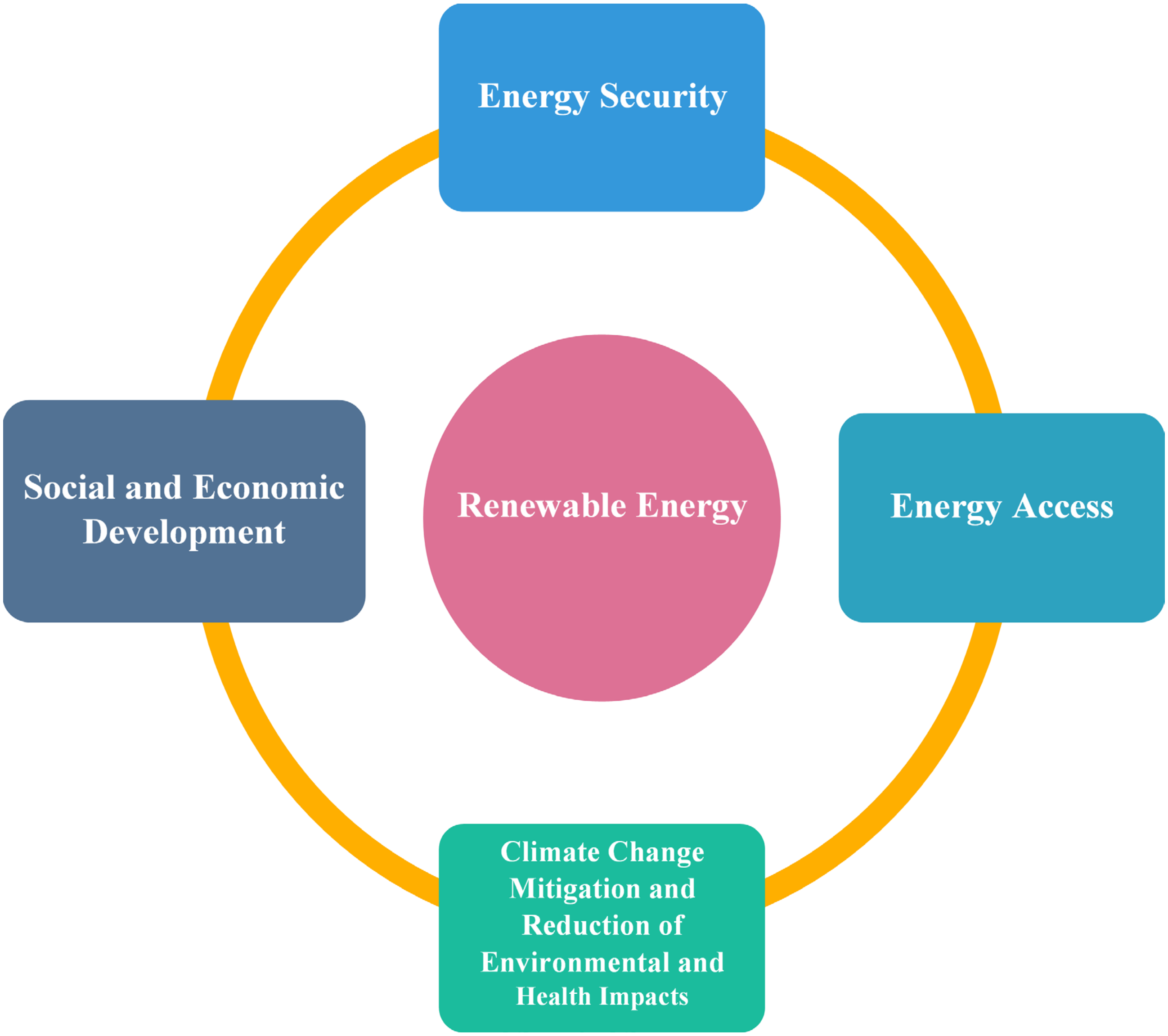

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A review of renewable energy sources, sustainability issues and climate change mitigation

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Abstract: The world is fast becoming a global village due to the increasing daily requirement of energy by all population across the world while the earth in its form cannot change. The need for energy and its related services to satisfy human social and economic development, welfare and health is increasing. Returning to renewables to help mitigate climate change is an excellent approach which needs to be sustainable in order to meet energy demand of future generations. The study reviewed the opportunities associated with renewable energy sources which includes: Energy Security, Energy Access, Social and Economic development, Climate Change Mitigation, and reduction of environmental and health impacts. Despite these opportunities, there are challenges that hinder the sustainability of renewable energy sources towards climate change mitigation. These challenges include Market failures, lack of information, access to raw materials for future renewable resource deployment, and our daily carbon footprint. The study suggested some measures and policy recommendations which when considered would help achieve the goal of renewable energy thus to reduce emissions, mitigate climate change and provide a clean environment as well as clean energy for all and future generations.

Subjects: Bio Energy; Clean Tech; Clean Technologies; Environmental; Renewable Energy

Keywords: renewable energy sources; climate change mitigation; sustainability issues; clean energy; carbon footprint; environmental sustainability engineering

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PUBLIC INTEREST STATEMENT

Energy is a requirement in our everyday life as a way of improving human development leading to economic growth and productivity. The return-to-renewables will help mitigate climate change is an excellent way but needs to be sustainable in order to ensure a sustainable future and bequeath future generations to meet their energy needs. Knowledge regarding the interrelations between sustainable development and renewable energy in particular is still limited. The aim of the paper is to ascertain if renewable energy sources are sustainable and examine how a shift from fossil fuel-based energy sources to renewable energy sources would help reduce climate change and its impact. A qualitative research was employed by reviewing peer-reviewed papers in the area of study. This study brought to light the opportunities associated with renewable energy sources; energy security, energy access, social and economic development and climate change mitigation and reduction of environmental and health impacts.

1. Introduction

The world is fast becoming a global village due to the increasing daily requirement of energy by all population across the world while the earth in its form cannot change. The need for energy and its related services to satisfy human social and economic development, welfare and health is increasing. All societies call for the services of energy to meet basic human needs such as: health, lighting, cooking, space comfort, mobility and communication and serve as generative processes (Edenhofer et al., 2011). Securing energy supply and curbing energy contribution to climate change are the two-over-riding challenges of energy sector on the road to a sustainable future (Abbasi & Abbasi, 2010; Kaygusuz, 2012). It is overwhelming to know in today's world that 1.4 billion people lack access to electricity, while 85% of them live in rural areas. As a result of this, the number of rural communities relying on the traditional use of biomass is projected to rise from 2.7 billion today to 2.8 billion in 2030 (Kaygusuz, 2012).

Historically, the first recorded commercial mining of coal occurred in 1,750, near Richmond, Virginia. Momentarily, coal became the most preferred fuel for steam engines due to its more energy carrying capacity than corresponding quantities of biomass-based fuels (firewood and charcoal). It is noteworthy that coal was comparatively cheaper and a much cleaner fuel as well in the past centuries (Abbasi, Premalatha, & Abbasi, 2011). The dominance of fossil fuel-based power generation (Coal, Oil and Gas) and an exponential increase in population for the past decades have led to a growing demand for energy resulting in global challenges associated with a rapid growth in carbon dioxide (CO_2) emissions (Asumadu-Sarkodie & Owusu, 2016a). A significant climate change has become one of the greatest challenges of the twenty-first century. Its grave impacts may still be avoided if efforts are made to transform current energy systems. Renewable energy sources hold the key potential to displace greenhouse gas emissions from fossil fuel-based power generating and thereby mitigating climate change (Edenhofer et al., 2011).

Sustainable development has become the centre of recent national policies, strategies and development plans of many countries. The United Nations General Assembly proposed a set of global Sustainable Development Goals (SDGs) which included 17 goals and 169 targets at the UN in New York by the Open Working Group. In addition, a preliminary set of 330 indicators was introduced in March 2015 (Lu, Nakicenovic, Visbeck, & Stevance, 2015). The SDGs place greater value and demands on the scientific community than did the Millennium Development Goals. In addressing climate change, renewable energy, food, health and water provision requires a coordinated global monitoring and modelling of many factors which are socially, economically and environmentally oriented (Hák, Janoušková, & Moldan, 2016; Owusu, Asumadu-Sarkodie, & Ameyo, 2016).

Research into alternate sources of energy dated back in the late 90s when the world started receiving shock from oil produces in terms of price hiking (Abbasi et al., 2011). It is evidential in literature that replacing fossil fuel-based energy sources with renewable energy sources, which includes: bioenergy, direct solar energy, geothermal energy, hydropower, wind and ocean energy (tide and wave), would gradually help the world achieve the idea of sustainability. Governments, intergovernmental agencies, interested parties and individuals in the world today look forward to achieving a sustainable future due to the opportunities created in recent decades to replace petroleum-derived materials from fossil fuel-based energy sources with alternatives in renewable energy sources. The recent launch of a set of global SDGs is helping to make sure that climate change for twenty-first century and its impacts are combated, and a sustainable future is ensured and made as a bequest for future generations (Edenhofer et al., 2011; Lu et al., 2015).

Against this backdrop, the study seeks to examine the potentials and trends of sustainable development with renewable energy sources and climate change mitigation, the extent to which it can help and the potential challenges it poses and how a shift from fossil to renewable energy sources is a sure way of mitigating climate change. To achieve this objective, concepts, techniques and peer-reviewed journals are analysed and reviewed judiciously.

The remainder of the paper is sectioned into five: Section 2 discusses renewable energy sources and sustainability and climate change, Section 3 elaborates on the various renewable energy sources and technologies, Section 4 elaborates on the renewable energy sources and sustainable development, Section 5 elaborates on challenges affecting renewable energy sources and policy recommendations and Section 6 concludes the study.

2. Renewable energy sources and sustainability

Renewable energy sources replenish themselves naturally without being depleted in the earth; they include bioenergy, hydropower, geothermal energy, solar energy, wind energy and ocean (tide and wave) energy. The main renewable energy forms and their uses are presented in Table 1.

Tester (2005) defines sustainable energy as, "a dynamic harmony between the equitable availability of energy-intensive goods and services to all people and preservation of the earth for future generations".

The world's growing energy need, alongside increasing population led to the continual use of fossil fuel-based energy sources (Coal, Oil and Gas) which became problematic by creating several challenges such as: depletion of fossil fuel reserves, greenhouse gas emissions and other environmental concerns, geopolitical and military conflicts, and the continual fuel price fluctuations. These problems will create unsustainable situations which will eventually result in potentially irreversible threat to human societies (UNFCC, 2015). Notwithstanding, renewable energy sources are the most outstanding alternative and the only solution to the growing challenges (Tiwari & Mishra, 2011). In 2012, renewable energy sources supplied 22% of the total world energy generation (U.S. Energy Information Administration, 2012) which was not possible a decade ago.

Reliable energy supply is essential in all economies for heating, lighting, industrial equipment, transport, etc. (International Energy Agency, 2014). Renewable energy supplies reduce the emission of greenhouse gases significantly if replaced with fossil fuels. Since renewable energy supplies are obtained naturally from ongoing flows of energy in our surroundings, it should be sustainable. For renewable energy to be sustainable, it must be limitless and provide non-harmful delivery of environmental goods and services. For instance, a sustainable biofuel should not increase the net CO_2 emissions, should not unfavourably affect food security, nor threaten biodiversity (Twidell & Weir, 2015). Is that really what is happening today? I guess not.

In spite of the outstanding advantages of renewable energy sources, certain shortcoming exists such as: the discontinuity of generation due to seasonal variations as most renewable energy resources are climate-dependent, that is why its exploitation requires complex design, planning and control optimization methods. Fortunately, the continuous technological advances in computer hardware and software are permitting scientific researchers to handle these optimization difficulties using computational resources applicable to the renewable and sustainable energy field (Baños et al., 2011).

Table 1. Renewable energy sources and their use (Panwar et al., 2011)

Energy sources	Energy conversion and usage options
Hydropower	Power generation
Morden biomass	Heat and power generation, pyrolysis, gasification, digestion
Geothermal	Urban heating, power generation, hydrothermal, hot dry rock
Solar	Solar home systems, solar dryers, solar cookers
Direct solar	Photovoltaic, thermal power generation, water heaters
Wind	Power generation, wind generators, windmills, water pump
Wave and tide	Numerous design, barrage, tidal stream

2.1. Renewable energy and climate change
Presently, the term "climate change" is of great interest to the world at large, scientific as well as political discussions. Climate has been changing since the beginning of creation, but what is alarming is the speed of change in recent years and it may be one of the threats facing the earth. The growth rate of carbon dioxide has increased over the past 36 years (1979–2014) (Asumadu-Sarkodie & Owusu, 2016c, 2016f), "averaging about 1.4 ppm per year before 1995 and 2.0 ppm per year thereafter" (Earth System Research Laboratory, 2015). The United Nations Framework Convention on Climate Change defines climate change as being attributed directly or indirectly to human activities that alters the composition of the global atmosphere and which in turn exhibits variability in natural climate observed over comparable time periods (Fräss-Ehrfeld, 2009).

For more than a decade, the objective of keeping global warming below 2 °C has been a key focus of international climate debate (Asumadu-Sarkodie, Rufangura, Jayaweera, & Owusu, 2015; Rogelj, McCollum, Reisinger, Meinshausen, & Riahi, 2013). Since 1850, the global use of fossil fuels has increased to dominate energy supply, leading to a rapid growth in carbon dioxide emissions. Data by the end of 2010 confirmed that consumption of fossil fuels accounted for the majority of global anthropogenic greenhouse gas (GHG) emissions, where concentrations had increased to over 390 ppm (39%) above preindustrial levels (Edenhofer et al., 2011).

Renewable technologies are considered as clean sources of energy and optimal use of these resources decreases environmental impacts, produces minimum secondary waste and are sustainable based on the current and future economic and social needs. Renewable energy technologies provide an exceptional opportunity for mitigation of greenhouse gas emission and reducing global warming through substituting conventional energy sources (fossil fuel based) (Panwar, Kaushik, & Kothari, 2011).

3. Renewable energy sources and technology
Renewable energy sources are energy sources from natural and persistent flow of energy happening in our immediate environment. They include: bioenergy, direct solar energy, geothermal energy, hydropower, wind and ocean energy (tide and wave).

3.1. Hydropower
Hydropower is an essential energy source harnessed from water moving from higher to lower elevation levels, primarily to turn turbines and generate electricity. Hydropower projects include Dam project with reservoirs, run-of-river and in-stream projects and cover a range in project scale. Hydropower technologies are technically mature and its projects exploit a resource that vary temporarily. The operation of hydropower reservoirs often reflects their multiple uses, for example flood and drought control (Asumadu-Sarkodie, Owusu, & Jayaweera, 2015; Asumadu-Sarkodie, Owusu, & Rufangura, 2015), irrigation, drinking water and navigation (Edenhofer et al., 2011). The primary energy is provided by gravity and the height the water falls down on to the turbine. The potential energy of the stored water is the mass of the water, the gravity factor ($g = 9.81\ ms^{-2}$) and the head defined as the difference between the dam level and the tail water level. The reservoir level to some extent changes downwards when water is released and accordingly influences electricity production. Turbines are constructed for an optional flow of water (Førsund, 2015). Hydropower discharges practically no particulate pollution, can upgrade quickly, and it is capable of storing energy for many hours (Hamann, 2015).

3.1.1. Hydropower source potential
Hydropower generation technical annual potential is 14,576 TWh, with an estimated total capacity potential of 3,721 GW; but, currently the global installed capacity of hydropower is much less than it's potential. According to the World Energy Council Report, about 50% of hydropower installed capacity is among four countries namely China, Brazil, Canada and USA (World Energy Council, 2013). The resource potential of hydropower could be altered due to climate change. Globally, the alterations caused by climate change in the existing hydropower production system are estimated to be

less than 0.1%, even though additional research is needed to lower the uncertainties of these projection (Edenhofer et al., 2011).

3.1.2. Hydropower environmental and social impact

Hydropower generation does not produce greenhouse gases and thus mostly termed as a green source of energy. Nonetheless, it has its advantages and disadvantages. It improves the socio-economic development of a country; but, also considering the social impact, it displaces a lot of people from their homes to create it, though they are compensated but are not enough. The exploitation of the sites for hydropower such as, reservoirs that are often artificially created leading to flooding of the former natural environment. In addition, water is drained from lakes and watercourses and transported through channels over large distances and to pipelines and finally to the turbines that are often visible, but they may also go through mountains by created tunnels inside them (Førsund, 2015). Hydroelectric structures affect river body's ecology, largely by inducing a change into its hydrologic characteristics and by disturbing the ecological continuity of sediment transport and fish migration through the building of dams, dikes and weirs (Edenhofer et al., 2011). In countries where substantial plants or tree covers are flooded during the construction of a dam, there may be formation of methane gas when plants start rotting in the water, either released directly or when water is processed in turbines (Førsund, 2015).

3.2. Bioenergy

Bioenergy is a renewable energy source derived from biological sources. Bioenergy is an important source of energy, which can be used for transport using biodiesel, electricity generation, cooking and heating. Electricity from bioenergy attracts a large range of different sources, including forest by-products such as wood residues; agricultural residues such as sugar cane waste; and animal husbandry residue such as cow dung. One advantage of biomass energy-based electricity is that fuel is often a by-product, residue or waste product from the above sources. Significantly, it does not create a competition between land for food and land for fuel (Urban & Mitchell, 2011). Presently, global production of biofuels is comparatively low, but continuously increasing (Ajanovic, 2011). The annual biodiesel consumption in the United States was 15 billion litres in 2006. It has been growing at a rate of 30–50% per year to achieve an annual target of 30 billion litres at the end of year 2012 (Ayoub & Abdullah, 2012).

3.2.1. Bioenergy source potential

Biomass has a large potential, which meets the goal of reducing greenhouse gases and could insure fuel supply in the future. A lot of research is being done in this area trying to quantify global biomass technology. According to Hoogwijk, Faaij, Eickhout, de Vries, and Turkenburg (2005) the theoretical potential of bioenergy at the total terrestrial surface is about 3,500 EJ/year. The greater part of this potential is located in South America and Caribbean (47–221 EJ/year), sub-Saharan Africa (31–317 EJ/year) and the Commonwealth of Independent States (C.I.S) and Baltic states (45–199 EJ/year). The yield of biomass and its potential varies from country to country, from medium yields in temperature to high level in sub tropic and tropic countries. With biomass, a lot of research is focusing on an environmentally acceptable and sustainable source to mitigate climate change (Demirbas, Balat, & Balat, 2009).

3.2.2. Bioenergy environmental and social impact

The use of biological components (plant and animal source) to produce energy has always been a cause of worry especially to the general public and as to whether its food produce are to be used to provide fuel since there are cases of food aid needed around the world in deprived countries. About 99.7% of human food is obtained from the terrestrial environment, while about 0.3% comes from the aquatic domain. Most of the suitable land for biomass production is already in use (Ajanovic, 2011). Current studies have underlined both positive and negative environmental and socio-economic effects of bioenergy. Like orthodox agriculture and forestry systems, bioenergy can worsen soil and vegetation degradation related with the overexploitation of forest, too exhaustive crop and forest residue removal, and water overuse (Koh & Ghazoul, 2008; Robertson et al., 2008). Diversion of crops or land into bioenergy production can induce food commodity prices and food security (Headey & Fan, 2008). Proper operational management, can bring about some positive effects which includes enhanced biodiversity (Baum, Leinweber, Weih, Lamersdorf, & Dimitriou, 2009; Schulz, Brauner, & Gruß, 2009), soil carbon increases and improved soil productivity (Baum, Weih, Busch, Kroiher, & Bolte, 2009; Edenhofer et al., 2011; Tilman, Hill, & Lehman, 2006).

3.3. Direct solar energy

The word "direct" solar energy refers to the energy base for those renewable energy source technologies that draw on the Sun's energy directly. Some renewable technologies, such as wind and ocean thermal, use solar energy after it has been absorbed on the earth and converted to the other forms. Solar energy technology is obtained from solar irradiance to generate electricity using photovoltaic (PV) (Asumadu-Sarkodie & Owusu, 2016d) and concentrating solar power (CSP), to produce thermal energy, to meet direct lighting needs and, potentially, to produce fuels that might be used for transport and other purposes (Edenhofer et al., 2011). According to the World Energy Council (2013), "the total energy from solar radiation falling on the earth was more than 7,500 times the World's total annual primary energy consumption of 450 EJ" (Urban & Mitchell, 2011).

3.4. Geothermal energy

Geothermal energy is obtained naturally from the earth's interior as heat energy source. The origin of the heat is linked with the internal structure of the planet and the physical processes occurring there. Although heat is present in the earth's crust in huge quantities, not to mention the deepest parts, it is unevenly distributed, rarely concentrated, and often at depths too great to be exploited mechanically.

Geothermal gradient averages about 30 °C/km. There are areas of the earth's interior which are accessible by drilling, and where the gradient is well above the average gradient (Barbier, 2002). Heat is mined from geothermal reservoirs using wells and other means. Reservoirs that are naturally adequately hot and permeable are called hydrothermal reservoirs, while reservoirs that are satisfactorily hot but are improved with hydraulic stimulation are called enhanced geothermal systems (ESG). Once drawn to the surface, fluids of various temperatures can be used to generate electricity and other purposes that require the use of heat energy (Edenhofer et al., 2011).

3.5. Wind energy

The emergence of wind as an important source of the World's energy has taken a commanding lead among renewable sources. Wind exists everywhere in the world, in some places with considerable energy density (Manwell, McGowan, & Rogers, 2010). Wind energy harnesses kinetic energy from moving air. The primary application of the importance to climate change mitigation is to produce electricity from large turbines located onshore (land) or offshore (in sea or fresh water) (Asumadu-Sarkodie & Owusu, 2016e). Onshore wind energy technologies are already being manufactured and deployed on large scale (Edenhofer et al., 2011). Wind turbines convert the energy of wind into electricity.

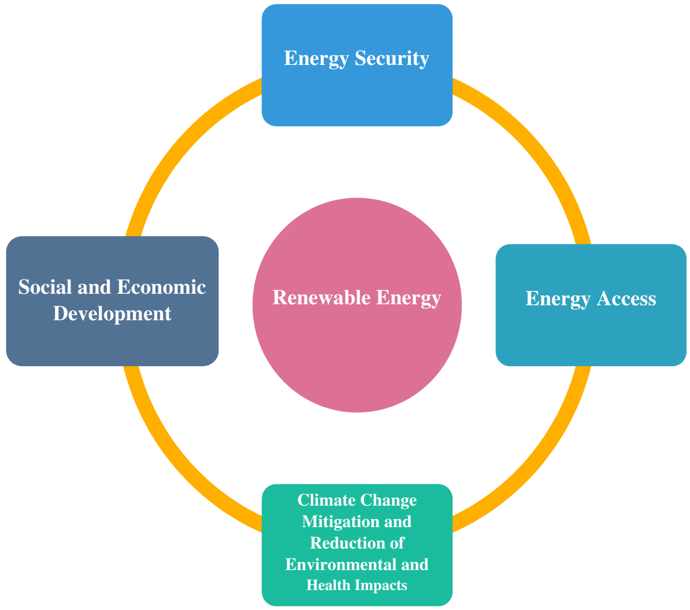
3.6. Ocean energy (tide and wave)

Surface waves are created when wind passes over water (Ocean). The faster the wind speed, the longer the wind is sustained, the greater distance the wind travels, the greater the wave height, and the greater the wave energy produced (Jacobson & Delucchi, 2011). The ocean stores enough energy to meet the total worldwide demand for power many times over in the form of waves, tide, currents and heat. The year 2008 saw the beginning of the first generation of commercial Ocean energy devices, with the first units being installed in the UK-SeaGen and Portugal-Pelamis. There are presently four ways of obtaining energy from sea areas, namely from Wind, Tides, Waves and Thermal differences between deep and shallow Sea water (Esteban & Leary, 2012).

4. Renewable energy and sustainable development

Renewable energy has a direct relationship with sustainable development through its impact on human development and economic productivity (Asumadu-Sarkodie & Owusu, 2016b). Renewable energy sources

Figure 1. Opportunities of renewable energy sources.



provide opportunities in energy security, social and economic development, energy access, climate change mitigation and reduction of environmental and health impacts (Asumadu-Sarkodie & Owusu, 2016g). Figure 1 shows the opportunities of renewable energy sources towards sustainable development.

4.1. Energy security

The notion of energy security is generally used, however there is no consensus on its precise interpretation. Yet, the concern in energy security is based on the idea that there is a continuous supply of energy which is critical for the running of an economy (Kruyt, van Vuuren, de Vries, & Groenenberg, 2009). Given the interdependence of economic growth and energy consumption, access to a stable energy supply is of importance to the political world and a technical and monetary challenge for both developed and developing countries, because prolonged interferences would generate serious economic and basic functionality difficulties for most societies (Edenhofer et al., 2011; Larsen et al., 2009). Renewable energy sources are evenly distributed around the globe as compared to fossils and in general less traded on the market. Renewable energy reduces energy imports and contribute diversification of the portfolio of supply options and reduce an economy's vulnerability to price volatility and represent opportunities to enhance energy security across the globe. The introduction of renewable energy can also make contribution to increasing the reliability of energy services, to be specific in areas that often suffer from insufficient grid access. A diverse portfolio of energy sources together with good management and system design can help to enhance security (Edenhofer et al., 2011).

4.2. Social and economic development

Generally, the energy sector has been perceived as a key to economic development with a strong correlation between economic growth and expansion of energy consumption. Globally, per capita incomes are positively correlated with per capita energy use and economic growth can be identified as the most essential factor behind increasing energy consumption in the last decades. It in turn creates employment; renewable energy study in 2008, proved that employment from renewable energy technologies was about 2.3 million jobs worldwide, which also has improved health, education, gender equality and environmental safety (Edenhofer et al., 2011).

4.3. Energy access

The sustainable development goal seven (affordable and clean energy) seeks to ensure that energy is clean, affordable, available and accessible to all and this can be achieved with renewable energy source since they are generally distributed across the globe. Access concerns need to be understood in a local context and in most countries there is an obvious difference between electrification in the urban and rural areas, this is especially true in sub-Saharan Africa and South Asian region (Brew-Hammond, 2010).

Distributed grids based on the renewable energy are generally more competitive in rural areas with significant distances to the national grid and the low levels of rural electrification offer substantial openings for renewable energy-based mini-grid systems to provide them with electricity access (Edenhofer et al., 2011).

4.4. Climate change mitigation and reduction of environmental and health impacts

Renewable energy sources used in energy generation helps to reduce greenhouse gases which mitigates climate change, reduce environmental and health complications associated with pollutants from fossil fuel sources of energy. The change in total GHG emissions in European Environmental Agency (EEA) countries for 1990–2012 and their GHG emissions per capita are depicted in Figures 2 and 3. Figure 2 shows that greenhouse gas emissions declined by 14% in 33 EEA countries between the years 1990–2012. Nevertheless, there was variation in individual member countries, while there was a decrease in GHG emissions in 22 EEA countries, there was an increase in 11 EEA countries. GHG emissions per capita declined by 22% between the years 1990–2012 in the EEA countries as depicted in Figure 3 (EEA, 2016).

Figure 4 shows United States carbon dioxide gas emissions from 1990–2013. Figure 2 shows an example of carbon dioxide emission levels being reduced from 1990–2013 in United States, a shift from mainly fossil fuel-based energy sources to renewable energy sources (United States Environmental Protection Agency, 2014).

5. Challenges affecting renewable energy sources

Renewable energy sources could become the major energy supply option in low-carbon energy economies. Disruptive alterations in all energy systems are necessary for tapping widely available renewable Energy sources. Organizing the energy transition from non-sustainable to renewable energy is often described as the major challenge of the first half of the twenty-first century (Verbruggen et al., 2010). Figure 5 shows the interconnection of factors affecting renewable energy supplies and sustainability. It is evident from Figure 5 that a major barrier towards the use of renewable energy source depends on a country's policy and policy instrument which in turn affect the cost and technological innovations. In addition, technological innovations affect the cost of renewable energy

Figure 2. Change in total GHG emissions in EEA-33 countries (1990–2012) (EEA, 2016).

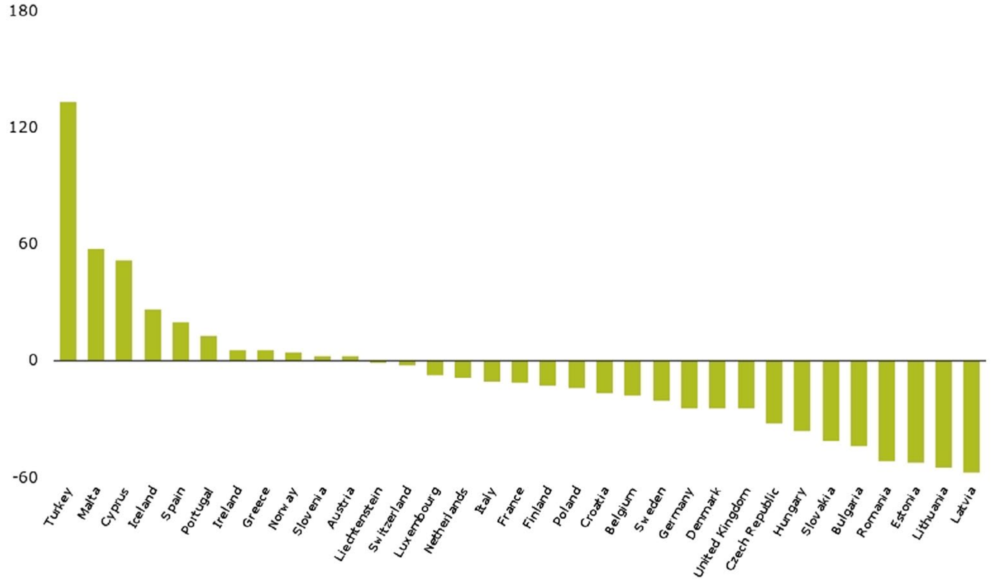


Figure 3. GHG emissions per capita in EEA-33 countries (EEA, 2016).

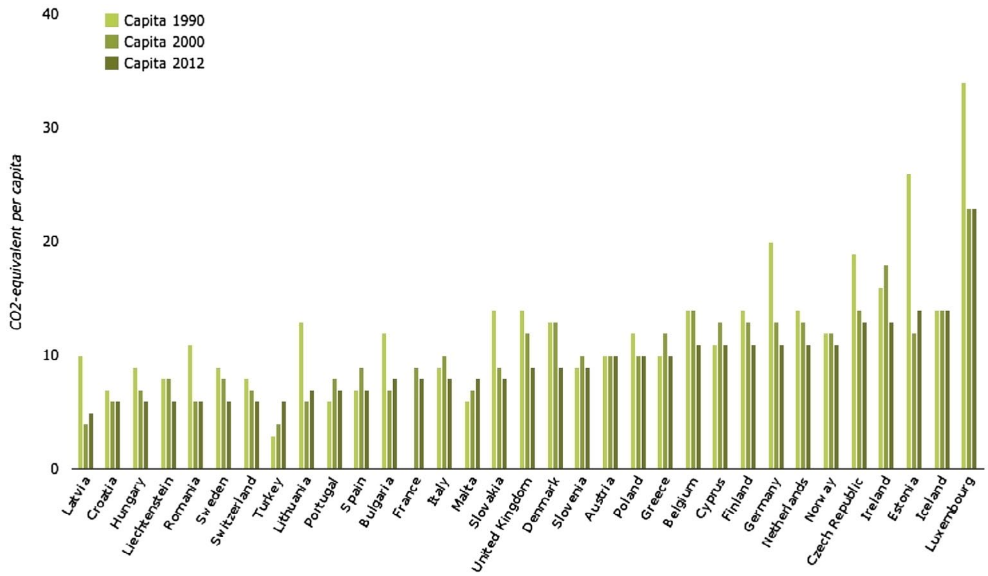
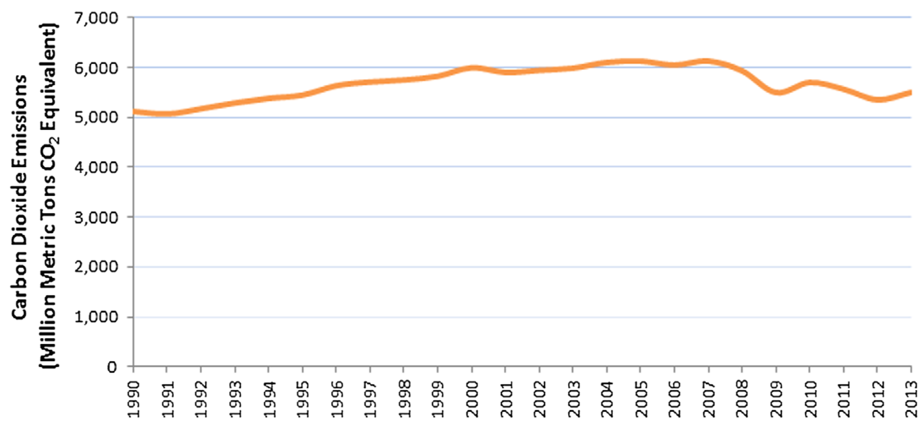


Figure 4. United States carbon dioxide gas emissions, 1990–2013 (United States Environmental Protection Agency, 2014).

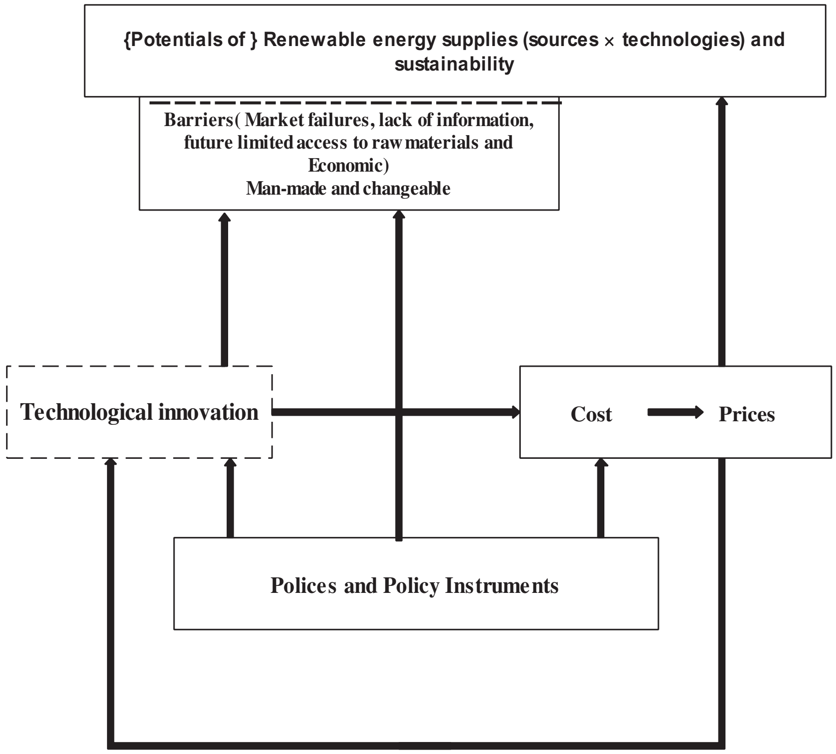


technologies which in turn leads to market failures and low patronization of the renewable energy technology. In the light of this, an effective renewable energy policy should take the interconnection of factors affecting renewable energy supplies and sustainability into consideration.

The following are policy recommendations emanating from the study that can help mitigate climate change and its impacts:

- All sectors and regions have the potential to contribute by investing in Renewable energy technologies and policies to help reduce it.
- Reducing our carbon footprint through the changes in lifestyle and behaviour patterns can contribute a great deal to the mitigation of climate change.
- Research into innovations and technologies that can reduce land use and also reduce accidents from renewable energy sources and the risk of resource competition, for example in Bioenergy where food for consumption competing with energy production.
- Enhancing international cooperation and support for developing countries towards the expansion of infrastructure and upgrading technology for modern supply and sustainable energy services as a way of mitigating climate change and its impacts.

Figure 5. Interconnection of factors affecting renewable energy supplies and sustainability, adapted from Edenhofer et al. (2011); Verbruggen et al. (2010).



6. Conclusion

Energy is a requirement in our everyday life as a way of improving human development leading to economic growth and productivity. The return-to-renewables will help mitigate climate change is an excellent way but needs to be sustainable in order to ensure a sustainable future for generations to meet their energy needs. Knowledge regarding the interrelations between sustainable development and renewable energy in particular is still limited. The aim of the paper was to ascertain if renewable energy sources were sustainable and how a shift from fossil fuel-based energy sources to renewable energy sources would help reduce climate change and its impact. A qualitative research was employed by reviewing papers in the scope of the study. Even though, the complete lifecycle of renewable energy sources have no net emissions which will help limit future global greenhouse gas emissions. Nevertheless, the cost, price, political environment and market conditions have become barriers preventing developing, least developed and developed countries to fully utilize its potentials. In this way, a creation of global opportunity through international cooperation that supports least developed and developing countries towards the accessibility of renewable energy, energy efficiency, clean energy technology and research and energy infrastructure investment will reduce the cost of renewable energy, eliminate barriers to energy efficiency (high discount rate) and promote new potentials towards climate change mitigation.

The study brought to light the opportunities associated with renewable energy sources; energy security, energy access, social and economic development and climate change mitigation and reduction of environmental and health impacts. There are challenges that tend to hinder the sustainability of renewable energy sources and its ability to mitigate climate change. These challenges are: market failures, lack of information, access to raw materials for future renewable resource deployment, and most importantly our (humans) way of utilizing energy in an inefficient way.

From the findings, the following suggestions are made that can help improve the concerns of renewable energy being sustainable and also reduce the rate of the depletion of the ozone layer due to the emissions of GHG especially carbon dioxide (CO_2):

- Formulation of policies and discussions from all sectors towards the improvement of technologies in the renewable sector to sustain them.
- Changes in our use of energy in a more efficient way as individuals, countries and the world as a whole. Efforts that aim at increasing the share of renewable energy and clean fossil fuel technologies into global energy portfolio will help reduce climate change and its impacts. Energy efficiency programmes should be introduced globally, which give tax exemptions to firms who prove to provide energy efficiency initiatives (energy-efficient homes), product design (energy-efficient equipment) and services (industrial combined heat and power). Introducing the concept of usability, adaptability and accessibility into energy-dependent product design is a way of promoting energy efficient behaviours.
- Increase research in these areas, so that the fear of some renewables posing risks in the future is limited.
- Improve education, awareness-raising and human institutional capacity on climate change mitigation, adaptation, impact reduction and early warning. Developed countries should incorporate decarbonization policies and strategies into the industry, energy, agricultural, forest, health, transport, water resource, building and other sectors that have potential of increasing greenhouse gas emissions. Efforts in developing countries aimed at improving institutional training, strengthening institutions and improving capacity of research on climate change will increase awareness, promote adaptation and sustainable development. Least developed countries should develop and test tools and methods with a global support that direct policy and decision-making for climate change mitigation, adaptation and early warnings. Supporting a global dialogue through international cooperation and partnership with developed, developing and least developed countries will promote the development, dissemination and transfer of environmentally friendly technologies, innovation and technology, access to science, and among others which will increase the mutual agreement towards combating climate change and its impacts.

If these suggestions are implemented, the sustainability of renewable energy resources would be addressed as well as the seventh and thirteenth goal of sustainable development which seeks to ensure access to affordable, reliable, sustainable, modern energy for all and combat climate change and its impact.

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