Environmental Effects of Solar PV, Diesel and the Corresponding Hybrids in Kenya: Case Study of Turkana County

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Abstract: **Renewable Energy (RE) is perceived to play an increasingly important role in fast-tracking accessibility to affordable electricity as an alternative to the nonconventional sources. The role of such REs in mitigating negative environmental effects has been given much emphasis. Developing isolated mini-grids has been one of the potential projects in scaling up RE to achieve rural electrification in line with Kenya's energy solar PV-Diesel Hybrid minigrids systems are discussed. Further, the proposed Simulation Software policies. In this paper, the environmental effects of solar PV Minigrid, Diesel minigrid and the corresponding (Homer) and the Case Study (Turkana County) are discussed.**

Key Words: Environmental Effects, Renewable Energy, Solar, Diesel, Hybrid and Homer

I: INTRODUCTION

World statistics currently indicate that over 1.5 billion people mainly in the rural areas and informal settlement of - lack access to electricity in most developing countries. Governments mostly in the developing countries must accelerate the universal access to electricity by investing heavily in the energy sector. As such, adoption of renewable energy is inevitable where through centralized mini-grids at the local level using village distribution network. Solar, wind and geothermal are the most common renewable energy sources. Hybrid systems where one or more renewable sources, a battery system or a diesel generator are integrated together to increase access to uninterrupted electricity that is environmentally friendly (Solar Power Awards, 2018).

Designing grid extension is costly in isolated rural communities and may not be feasible in implementation. However, renewable energy generation sources can be integrated together to come up with an affordable hybrid system that can impact the end users. Even though the nature of rural economies pushes for low-cost energy programs, quality has affected the system's lifespan, and thus the superiority of the system components can guarantee a long-lasting program with lowest generation costs. Appropriate sizing of the system increases the efficiency gains and cost savings, thus energy efficiency. The load and the power generated by a system is affected by the energy efficiency and raises the cost of the project. As a result, energy policies in developing Countries should be established by supply and demand-side management. In designing household and community energy systems many designers advice on the consumers on how to reduce short-term investment costs, thus the need for creating awareness on energy-efficient appliances (Alliance for Rural Electrification, 2017).

In sub-Saharan Africa, energy sources such as diesel are used to distribute energy in arid and semi-arid communities. However, a system that is served entirely by diesel gen sets is more expensive than hybrid ones. Hybrid mini-grids, on the other hand, exploit several local renewable resources combined with the gen-sets to complement one another (ARE n.d.).

Turkana County is one of the counties that is powered by off-grid mini-grids powered by diesel generators and with the highest poverty index in Kenya. According to Turkana County Government (n.d.), nearly 92 percent of the population -earns less than two US dollars per day (Turkana County Integrated Development, 2013-2017). Being a solar energy potential zone, with an average potential of around 4-6 kWh/m2, solar PV modules can be used to convert the solar radiation into electricity (RECP, 2018). Solar PV system is a form of clean energy that can be a great substitute of diesel gen set or a fuel saver for a hybrid (Solar-Diesel) system mini-grid. Hybrid power systems have recently attained a lot of attention worldwide owing to their ability to combine several renewable energy sources and also include a backup generator as well as reducing emissions from the petroleum energy sources (WIT Press n.d.).

II: ENVIROMENTAL EFFECTS

A: Solar PV Mini-grid

Ideally, solar PV energy adoption is viewed to have environmental benefits over the conventional diesel mini-grid (Boateng, 2016; Tsoutsos et al., 2005). These benefits link the low carbon/greenhouse gas emissions of solar PV generation and utilization. Olatomiwa, Mikhilef, Huda, & Sanusi (2015) in their study stated that adoption of the conventional DG hybrided with renewable enery - would not only reduce diesel consuption and operating cost ,it would also signifiantly decrease the operating hours of the DG leading to reduction in greenhouse gas emissons. .

A study carried out by Anayochukwu & Nnene (2013) on measuring the environmental impact of power generation at GSM Base station sites, concluded that “it is important to quantify the environmental impact of using DG in GSM base stations. l Greenhouse gases (GHG) pollute the environmentand adversely affect the life of human beings.Indirect impacts generated by GHGs affect the quality of health.. Jade (2011) carried out a study comparing the environmental impacts of DG with hybrid diesel-wind electricity for off-grid communities in Ontario incorporating a Life Cycle Approach. The study evaluation determined that “although designers cannot entirely avoid diesel generated energy, hybrid diesel-wind does have the potential to provide reductions in environmental impacts between 12-46% when comparing it to the diesel generator system. The LCA indicated that the seven First Nations off-grid communities analyzed have the potential to reduce their environmental impacts caused by diesel generated electricity production through the implementation of hybrid-diesel wind” (Jade, 2011). The reduction was determined to be dependent on the renewable energy sources penetration level.

a) Positive Environmental Impact

Green Technology: Solar PV mini-grid is considered a green technology because it offers no pollution to the environment, the air remains fresh. It replaces the tradition and conventional energy sources from coal power plants that increase the content of Sulphur in the atmosphere thus causing acid rain, and petrochemicals such as gasoline, where carbon (I1) oxide is released, and other toxic substance of public health concerns.

Reduction in Green House Effect: Global warming is an international concern to different governments around the world. There have been summits of various world leaders to make the earth habitable, and hence global warming is a threat to humanity. Solar energy is a promising technology that offers no emission of greenhouse gases and carbon dioxide (Akyuz *et al.*,2018).

b) Negative Environmental Impact

Solar PV Mini-Grid plants have the potency to cause environmental degradation and the loss of habitat. The degree of damage depends on the scalability of the technology, the land topography and the resources available for construction of the site. The materials to be used are proportional to the type of technology, like photovoltaic (PV) solar cells. For PV it requires about 3.5 to 10 acres per megawatt. Another factor to be considered is that it is unlikely for the solar system to share the land with agricultural uses (scientist, 2013).

Solar systems design materials require maintenance and cleaning. Cleaning of these surfaces makes use of chemicals which are relatively toxic to humans. These chemicals include , hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1, 1, 1-trichloroethane and acetone which are similar to chemicals used in the semiconductor industry. The amount of these substances used depends on the type of solar system as iterated.

There were health complications when the storage units used to store heat energy is not ideal. Consequently, this may provide the perfect environment for the growth of molds and fungi that causes a different allergic reaction. It is also worth noting that the need for renewable energy is inexhaustible, but comes with its challenges. Thus, it might cause a shift in the ecological balance, owing to the facts that the surfaces of these panels reflect light because of silicon-based materials in their structure. When birds and insect fly around this region, they may die, hence affecting ecological patterns in the environment.

B: Diesel Mini-Grid

a) Positive Environmental Impact

The environmental impacts of diesel mini-grids are quite severe. So far there are no direct positive environmental impacts of diesel engines. However, the emission of CO2 has adverse effects on the environment as well as in the maintenance of life on earth. Ideally, human civilization should prevent carbon dioxide from trending down to ranks that impend the survival of living things that depend on it.

All life in the universe is carbon based and that the source of this carbon is CO2, which sequences through the global atmosphere by either natural or human processes. According to GREENIE WATCH. (n.d.) and Moore (2016), "as a minor gas at 0.04%, CO2 infiltrates the entire atmosphere and has been absorbed by the oceans and other water bodies (the hydrosphere), where it provides the food for photosynthetic species. If there were no CO2 or an insufficient level of CO2 in the atmosphere and hydrosphere, there would be no life as we know it on our planet" (GREENIE WATCH. (n.d.)).

b) Negative Environmental

Diesel is made up of carbon elements and thus discharges a mass of harmful materials together with direct emissions as Universiti Tenaga Nasional. (n.d.) posits that diesel contains "organic and elemental carbon (soot), toxic metals, nitrogen oxides that form ozone and nitrate particulate matter, volatile organic compounds, carbon monoxide (CO), carbon dioxide (CO2), and a variety of toxic metals and gases such as formaldehyde, acrolein and polycyclic aromatic hydrocarbons" (Universiti Tenaga Nasional. (n.d.); Anayochukwu and Nnene, 2013).

Inhalation of these toxic substances can cause cancers, cardiovascular diseases, respiratory diseases, and others. These substances include carbon (II) oxide and other toxic gasses. Diesel combustion discharges fine particles and toxic gases that can enter the body circulation system through the lungs once inhaled. It additionally can accumulate in lungs over time, hindering oxygen exchange to the blood and causing numerous health problems. Such as chronic respiratory symptoms such as shortness of breath and painful breathing; asthma; bronchitis; cancer; and premature deaths (NJDEP - StopTheSoot.org. (n.d.)).

One significant effect of these gases is the ability to cause greenhouse effect, and global warming, which in turn leads to deforestation, and degradation of agricultural lands, coupled with air and water pollution, the accumulation of solid waste, formation of smog and finally the extinction of some flora and fauna of various water bodies (Oisamoje & Eguono, 2013). Diesel machines produce so much noise that can irritate the ears, and cause noise pollution, repeated exposure of sound of a specific frequency can increase the chances of losing hearing.

C Solar PV Diesel- Hybrid Mini-Grid

a) Positive Environmental Impacts

An intelligent system optimizes the hybrid system that autoregulates itself depending on the energy demand per time. This optimization helps in the reduction of emissions from carbon, and toxic waste, hence a modification of the greenhouse effect and global warming gearing towards a smart environmental friendly system.With the development of a hybrid system, it compensates for the noise produced by diesel generators, hence controlling noise pollution while achieving the same purpose of energy satisfaction (Othman, 2005).

b) *Negative Environmental Impact*

One primary adverse environmental effect of a hybrid power system is that it's not emission free. There are still some quantities of toxic substances that are emitted to the environment, though minimal. These toxic substances can still bio-accumulate in the human system and cause public health issues. The emission of greenhouse gases always accompanies hybrid systems. Hence the earth is still not entirely free from the dangers it brings (Usman et al., 2017).

III: HOMER SOFTWARE

HOMER means Hybrid optimization Model for Electric Renewable. It is a software that is used for the designing, modelling and analysis of renewable energy systems. Renewable Energy Laboratory of the US developed it with an aim of coming up with more efficient renewable energy micro grid and has over time evolved to be a tool to design smart, more environmentally friendly energy micro grids.

The Homer software utilizes inputs as load demand and the available energy resources as well as the components of the power system in its calculations to design an optimal system. It reviews all available energy sources in all possible combinations. The design and analysis process is at times tasking due to uncertainties such as cost of fuel and power as well as future load size. To determine the hybrid system size using the software, an optimum system statement is formulated that minimizes the construction and operation costs with the maximum possible allowed risk determined. To do this, parameters such as wind speed, solar irradiation and load profile are determined.

System optimization is done after considering several combinations of hybrid renewable energy solutions based on the total net present cost (TNPC). The optimal system is the one with the lowest TNPC. The content and the weakness for the software is as shown in Table 1.

Table 1: HOMER SOFTWARE

Content	Deficiency/Weakness
• Designing, modelling and analysis of renewable energy systems by considering wind speed, solar irradiation and load profile. • Optimization of renewable energy system based on the lowest TNPC	• Only considers CO_2 emissions in its analysis of RE systems • Does not consider social impacts directly • Does not consider health impacts directly

IV: PROPOSED CASE STUDY

This research seeks to establish the economic and environmental impacts of solar PV integration into the existing diesel mini-grid in Turkana County. According to Turkana County Government (2013), “Turkana County is situated in North Western Kenya. It borders West Pokot and Baringo Counties to the South, Samburu County to the South East, and Marsabit County to the East. Internationally it borders South Sudan to the North, Uganda to the West and Ethiopia to the Northeast. The County shares Lake Turkana with Marsabit County. The total area of the county is 77,000 KM2 and lies between Longitudes 340 30’ and 360 40’ East and between Latitudes 10 30’ and 50 30’ North”. The map of the county plus the daily solar irradiance is shown n Figure 1.

The County population stood at 855, 399 according to the Kenya Population and Housing Census (KPHC) results. The population is projected to be 1,036, 586 in 2012 and 1,427,797 in 2017 based on a population growth rate of 6.4 percent assuming constant mortality and fertility rates (Turkana County Government CIDP. (2013)”.

The research study is focusing on Turkana County, one of the regions powered by off-grid connection (diesel mini-grids) located in 4 town centers namely Lodwar, Lokichoggio, Lokori and Lokitaung with two more (Kakuma and Lokiriama) under construction. The Population densities in these towns are low with a population of 146,275 people, and the lifestyle is predominantly pastoral. These towns are deficient regarding access to electricity supply.

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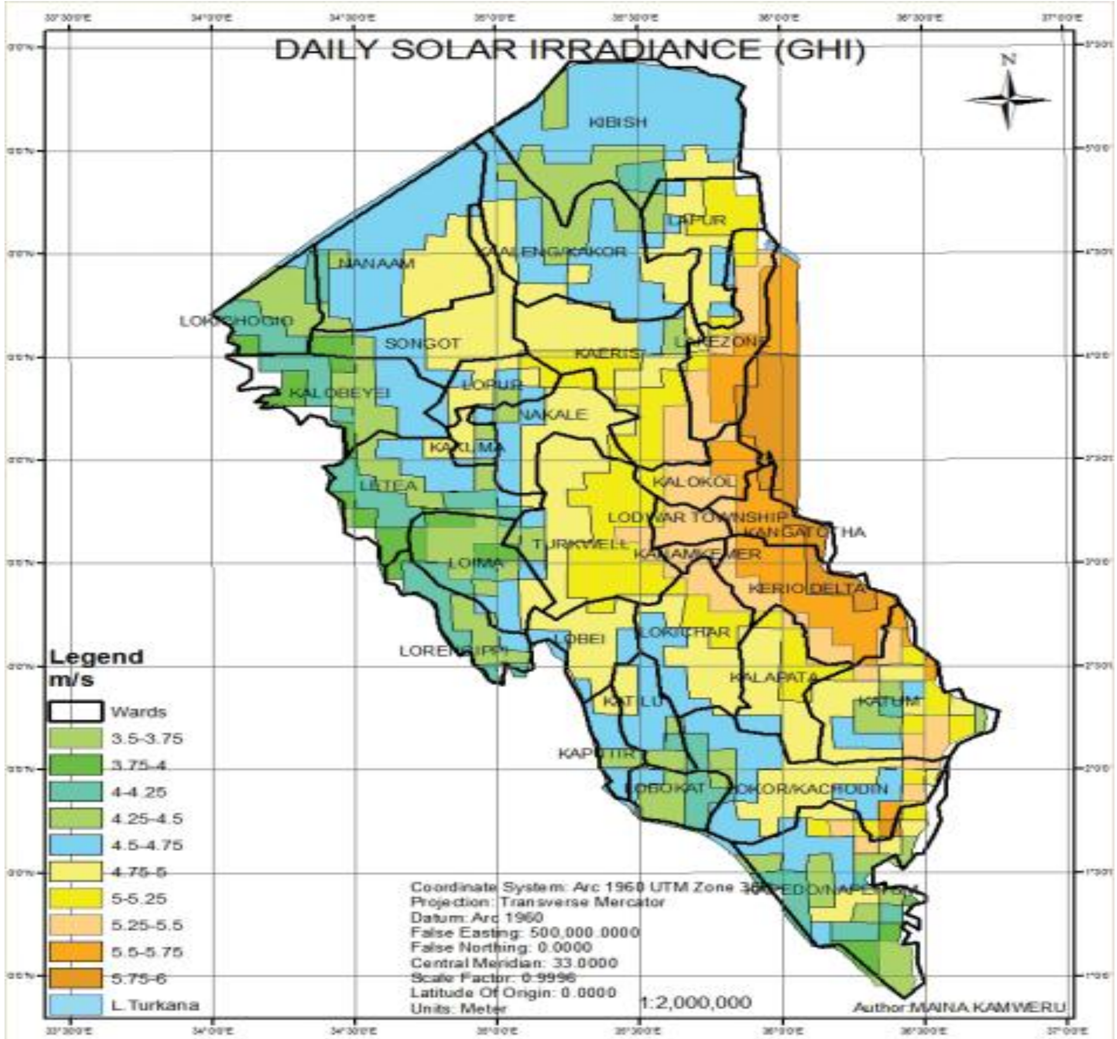

Figure 1: Daily solar Irradiance of Turkana County:
Source :*(Turkana County Resource Maps, 2016)*

V: CONCLUSION

In this paper, environmental impacts of solar, diesel and the corresponding hybrid system are presented. It is apparent that the Hybrid methods are more environmental friendly as compared to the individual sources. Further, the proposed simulation method; Homer is introduced and its capability to handle environmental issues illustrated. Lastly, Turkana County in Kenya, which is the Case Study; have been described. The proposed research study will present a hybrid power system of a standalone PV system and diesel generator and thus investigate the economic and environmental impacts of Solar PV integrated into a diesel mini-grid in Turkana County. Further work shall include the formulation of the Hybrid System and the environmental effects and analysis of the simulated results.

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