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The Role of Solar Power in Enhancing Sustainable Energy in Electricity Generation Mix Across Ghana

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Abstract

Sustainable energy is a key driver in the preservation of the environment and the development of Economies, and Society. Sustainable energy, solar power is one of them, is more concerned with how energy needs can be met today, and tomorrow for generations yet unborn. Energy supply from sustainable sources is significant for United Nations Sustainable Development Goals (SDGs) because of its clean and climate action. Therefore, the study examined a qualitative assessment of solar energy's role in enhancing energy security, and environmental sustainability in the electricity generation mix in Ghana. The research uncovers some findings through a qualitative analysis of downloaded papers from the Energy Commission of Ghana and the Ministry of Energy to supplement peer-reviewed scholarly literature. The study revealed that solar energy installed and connected to the grid is 143.9 MW representing 3% of the electricity generation mix despite Ghana's substantial solar energy potential. The 143.9 MW is insufficient to guarantee the country's energy security. Again, it was discovered that in response to the global call for a cohesive approach to tackle the challenges of climate change, developing more solar energy would offset the country from millions of tonnes of greenhouse gas emissions. This would save the environment and contribute favourably to Ghana's Nationally Determined Contribution in response to the Paris agreement in 2015. An effective solar energy master plan is needed for the massive development of solar energy because of the abundance of solar potential in Ghana.

Keywords: Sustainable Energy; Solar Energy; Electricity.

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1. Introduction

Renewable energy, especially solar, biomass, and wind are Ghana's most gifted energy resources [1]. Among these gifted energy sources, hydropower has been the dominant source of electricity supply for Ghana for many decades until recently when electricity supply from thermal generation exceeded that of hydropower. Until 1998, most of Ghana's electricity was produced from two hydropower plants at Akosombo and Kpong. However, the commission of the Bui Hydroelectric Power Plant in 2013 has brought major hydropower plants to three. The accomplishment of Akosombo Dam in 1972 brought in an installed capacity of 912MW, and in 1982 Kpong Hydropower was commissioned with an installed capacity of 160MW. For all those years, the power supply in the country was stable until between 1982 and 1984 when a severe drought hit the nation and brought about a power crisis known in Ghana these days as "Dumso". This event was the first-ever electricity shortage experienced due to inadequate inflows into Akosombo and Kpong hydroelectric dams. This electrical energy shortage led to the introduction into the country of Thermal power plants, the electrical energy that reduced the over-dependence on hydroelectric power [2].

Again, climate change is one of the crucial encounters to hydropower generation. There is much hydropower potential in Ghana, which could be harnessed to provide energy at a reasonable cost to support the economic development of Ghana. However, the trend of rainfall patterns due to climate change is becoming alarming, posing a threat to its sustainability. Sustainable energy, solar power is one of them, is more concerned with how energy needs can be met today, and tomorrow for generations yet unborn [3]. Therefore, the climate situation presents a risk to the development of further hydropower plants to ensure energy security in Ghana. Moreover, introducing the thermal power plant into the country's energy mix was key because it came to close the electrical energy deficit of the country. The thermal power plants operate on fossil fuels. However, fossil fuel is known to be among the highest sources of greenhouse gas emissions which is unsustainable, and unfriendly to the natural setting and hence causes climate change. Therefore, energy supply from sustainable sources is significant for United Nations Sustainable Development Goals (SDGs) because of its clean, and climate action.

In addition, the current predicament in Ukraine has created a different view and uncertainty in the price of fossil fuels. Developing countries such as Ghana may not be able to meet the high cost of fossil fuels. Meanwhile, Ghana should attain its manufacturing and financial goals through sustainable electricity generation to ensure energy security and environmental sustainability. Therefore, Ghana must have a dependable strategy to deliver sustainable energy [4]. High fossil fuel prices cause energy poverty, destroy industrial competition, raise energy bills, and intensify climate issues [5]. Solar energy presents better security from commodity price fluctuations than fossil fuel prices. This paper seeks to examine a qualitative assessment of the role of solar energy in enhancing energy security and environmental sustainability in the electricity generation mix in Ghana. The research uncovers some findings through a qualitative analysis of downloaded papers from the Energy Commission of Ghana, and the Ministry of Energy to supplement peer-reviewed scholarly literature.

2. Solar Energy Potential in Ghana

There is sufficient evidence to show the potential of Ghana's solar radiation across the country. There is

dependable solar radiation between 4KWh/m²/day, and 6KWh/m²/day to aid electricity generation on-grid and off-grid [6]. The country can benefit tremendously from the free solar energy available, as shown in figure 2.1 which indicates very low diffuse radiation of 32% in the Northern part of Ghana. It is based on low diffuse solar radiation in the Northern part of Ghana that made the state-owned electricity generation company "Volta River Authority" to build solar power plants in the Northern part of Ghana with an installed capacity of 22 MW. The Sustainable Development Goal (SDG) number seven (7) guarantees universal access to cheap, dependable, and clean energy and has been approved by the country. The private sector in Ghana is also contributing significantly to the building of solar energy but it is not enough to sustain the electrical energy demand in the country. It has become very necessary for Ghana to take advantage of the abundance of solar energy to produce clean energy, and also, to protect the environment.

However, it offers a great challenge to Ghana because the country still counts on fossil fuel energy sources for power generation [7]. Ghana has an installed power generation capacity with a mixture of thermal, hydro, and solar. The thermal generation has the highest installed capacity of 68%, 28% for hydro and 3% for solar respectively as of July 2022. Moreover, over the years, global renewable energy has increased investment especially in solar photovoltaics (PV) in many countries. As of 2005 solar PV has soared from 3.1GW to 227GW in 2015. Again, the Government of Ghana has already recognized renewable energy as a critical contributor to the electrical energy supply mix that would reduce the undesirable impact of energy production on the environment [8]. Ghana has achieved some success in solar energy because as of July 2022 the country could boast of on-grid solar power of about 143.9MW installed capacity, which is still less than the installed thermal capacity. The high percentage of thermal in Ghana's electrical energy mix clarified that the country is releasing more carbon emissions into the atmosphere when there is more sun energy with an average sun hour ranging from 1800 hours to 3000 hours annually. The country must take advantage of the solar resources available to generate clean energy to protect the environment.

Moreover, under Ghana's energy sector strategy and development plan, the goal that was set for renewable energy was to contribute 10% of the national energy generation in the year 2020 but the country failed to achieve the said target. Due to the failure, the country has shifted the target of 10% of national energy generation to 2030 [1]. It is very imperative for Ghana to take advantage of the abundance of solar energy potential in the entire country to achieve the set target and beyond to generate cheaper electricity. The Volta River Authority, a state-owned electricity generation company, has solar power plants installed in some parts of the Northern Region, including Navrongo 2.5 MW, Lawra 6.5 MW, and Kaleo 13MW currently on the grid. Bui Power is another state-owned electricity generation company with a solar power plant with an installed capacity of 51 MW. Furthermore, there are other independent power producers (IPPs) such as BXC Solar plant 20 MW, Meinergy solar plant 20 MW and other Distributed Solar power plant 30.9 MW all on the grid as of July 2022. The private sector in Ghana is contributing a lot to the development of solar energy.

The northern and southern parts of Ghana have much solar radiation with low and moderate diffuse radiation for the success of generating both on-grid and off-grid electricity in Ghana. However, with the abundance of solar radiation in the country, most especially in the northern part of Ghana, it is only in Navrongo, Lawra and Kaleo that the country has an installed capacity of 2.5 MW, 6.5MW, and 13 MW respectively.

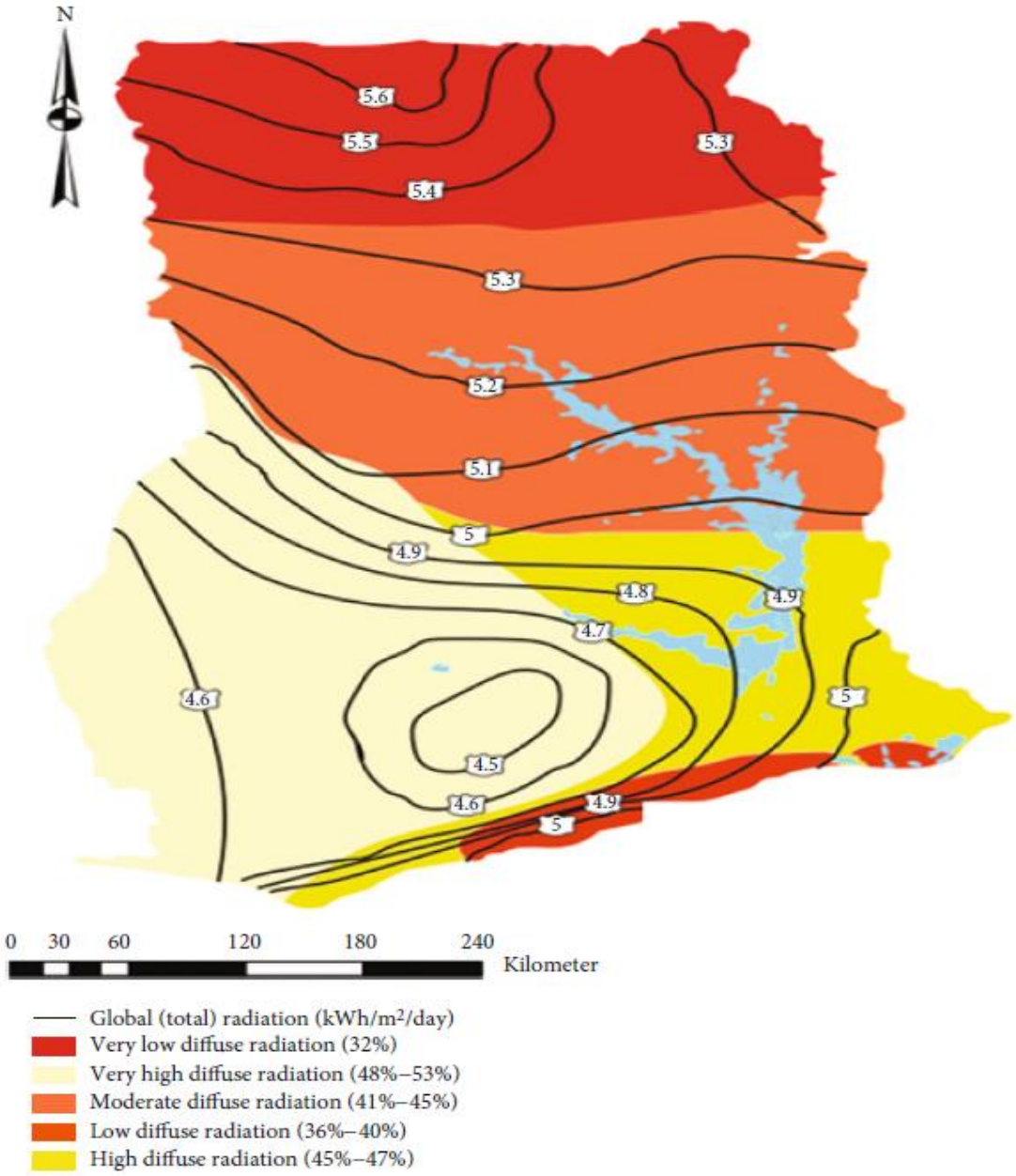

Figure 2.1: Solar Radiation in Ghana [6]

Again, with the renewable energy master plan of Ghana, it has a time span from 2019 to 2030 with the view that if it implemented successfully the country would have an installed renewable energy totaling 1,363.63 MW, with expected carbon saving close to 11 million tonnes of CO_2 by 2030 and also create many job opportunities for the youth. As part of the renewable energy master plan for the country, the government of Ghana is expecting 80% of the investment into renewable energy to come from the private sector. The total cost of the renewable energy investment master plan is approximated to be US$ 5.6 billion. It is very urgent for the government of Ghana to make sure that the incentives provided in the master plan to give tax rebate for the private sector is well implemented so that by the year 2030 as documented in the renewable energy master plan would be accomplished [8].

3. The Role of On-grid Solar Energy in Ghana

There is a massive potential for solar energy capacity across the country but only a few megawatts are connected to the grid as indicated in Table 1.1 as of 2021. Meanwhile, on average, there is a lot of dependable solar radiation which ranges from 4.0 kwh/m^2 to 6.5kwh/m^2 according to the Energy Commission of Ghana, per year within the country, with a sunshine duration between 1800 to 3000 hours per year [6].

Table 1.1: Installed Solar Plant Generation Capacities in Ghana as of 2021 on-grid (MW) [9]

SOLAR PHOTOVOLTAIC (PV) ON-GRID			
#	**Solar Plant**	**Installed Capacity (MW)**	**Dependable Capacity (MW)**
1	VRA Solar (Navrongo)	2.5	2
2	VRA Solar (Lawra)	6.5	4.5
3	VRA Solar (Kaleo)	13	10
4	BXC Solar	20	16
5	Meinergy	20	16
6	Bui Solar	51	46
7	Distributed Solar PV	30.9	-
Total Installed Capacity = 143.9 MW			

Furthermore, the total installed on-grid solar plant capacity in Ghana is 143.9 MWp as of 2021 to date, while the solar energy potential in Ghana far exceeds the already installed solar power on the grid. Average solar radiation in Ghana is between 4KWh/m^2 – 6.5KWh/m^2 [6]. The average solar power radiation signifies that the country can generate more solar energy to power the economy of Ghana. The already installed solar power on the grid plays a significant role in the power generation mix of Ghana. That is, the 13MW solar power already installed at Kaleo in the Upper West Region of Ghana has been purchased by the Newmont Ghana Limited to also show their commitment to the sustainability of the environment by using clean solar energy.

4. The sustainability of the environment

Energy use in the environment has a major influence on the natural setting. Using biomass for energy causes deforestation that destroys the environment and increases carbon emission footprint. Fossil fuels add up to carbon dioxide emissions. The production and transportation of crude oil have a huge negative effect on the environment [10]. The ability to sustain the environment would be driven by clean energy such as solar energy. The vast amount of fossil fuel used in the electricity generation mix in Ghana supersedes any other source of energy currently applied. If measures are not taken as a matter of urgency to curtail fossil fuel use, our environment and future generation life cannot be guaranteed. Table 1.2 below illustrates the electrical energy generated from thermal plants that use fossil fuels, meanwhile there is an urgent need for countries to reduce their carbon footprint as part of the Paris Agreement for the country to contribute meaningfully to Nationally Determine Contribution (NDC).

Table 1.2: Installed Thermal Power Plants in Ghana in MW as of 2021 [9]

THERMAL POWER PLANTS			
#	**Thermal Plant**	**Installed Capacity (MW)**	**Dependable Capacity (MW)**
1	Takoradi Power Company (TAPCO)	330	300
2	Takoradi International Company (TICO)	340	320
3	Tema Thermal 1 Power Plant (TT1PP)	110	100
4	Tema Thermal 2 Power Plant (TT2PP)	87	70
5	Cenit Energy Ltd	110	100
6	Kpone Thermal Power Plant	220	200
7	Ameri Plant	250	230
8	Sunon Asogli Powers (Ghana) Ltd	560	520
9	Karpowership	470	450
10	Trojan	44	39.6
11	Amandi	203	190
12	AKSA	370	350
13	Cenpower	360	340
14	Early Power / Bridge	144	140
15	Genser	155	131
TOTAL	**3,753 MW**	**3,480.6 MW**	

However, according to the Energy Commission of Ghana, the electricity demand growth is expected to be 10% yearly, with an additional capacity of about 200 MW. Therefore, the projected electrical energy demand for 2030 is estimated to be about 40,000 GW, as indicated in figure 1.3 [11]. The dominance of fossil fuels cannot accomplish the estimated 40,000 GWh because of environmental concerns and climate change issues, therefore, the use of solar energy which is the most abundant in Ghana should be utilized to minimize the negative effect of fossil fuels on the environment. The contribution of solar energy to the electricity generation mix is significant even though thermal power generation is the highest in Ghana's electricity generation mix.

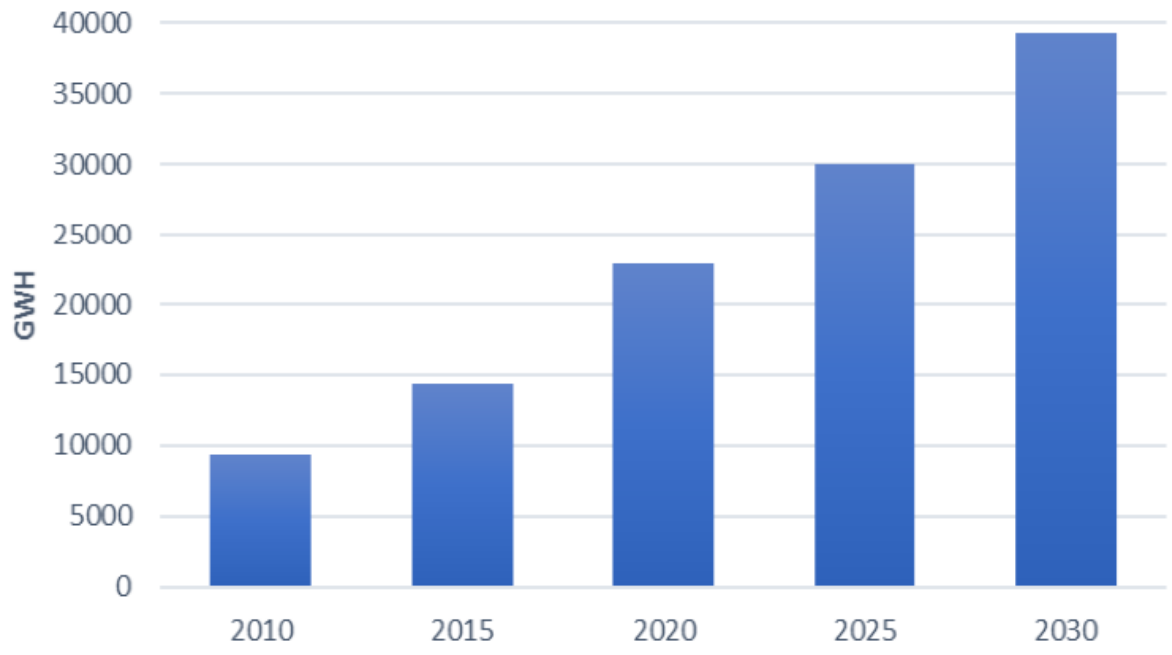

Figure 1.3: Projected Electricity Demand of Ghana [11]

Furthermore, Hydropower has been the dominant source of electricity supply for Ghana for many decades until recently when electricity supply from thermal generation has exceeded that of hydropower. Until 1998, most of Ghana's electricity was produced from two hydropower plants at Akosombo and Kpong [12]. The total installed hydropower plants in Ghana are listed in Table 1.4 below.

Table 1.4: Hydropower Plants in Ghana as of 2022 [9]

HYDROPOWER PLANTS			
#	Hydropower Plant Location	Installed Capacity (MW)	Dependable Capacity (MW)
1	Akosombo Hydropower Plant	1020	900
2	Kpong Hydropower Plant	160	140
3	Bui Hydropower Plant	404	360
Total		1,584	1,400

The contribution of solar, hydro and thermal generation to the country's electrical energy mix is very significant. However, the percentage contribution of each power plant is found in figure 1.4 and Table 1.5 illustrates the contribution from the three sources as shown.

Table 1.5: Total Power On-Grid in Ghana

Total Installed Solar PV Plants in Ghana (MW)	Total Installed Hydro Power Plants in Ghana (MW)	Total Installed Thermal Power Plants in Ghana (MW)
143.9	1,584	3,753

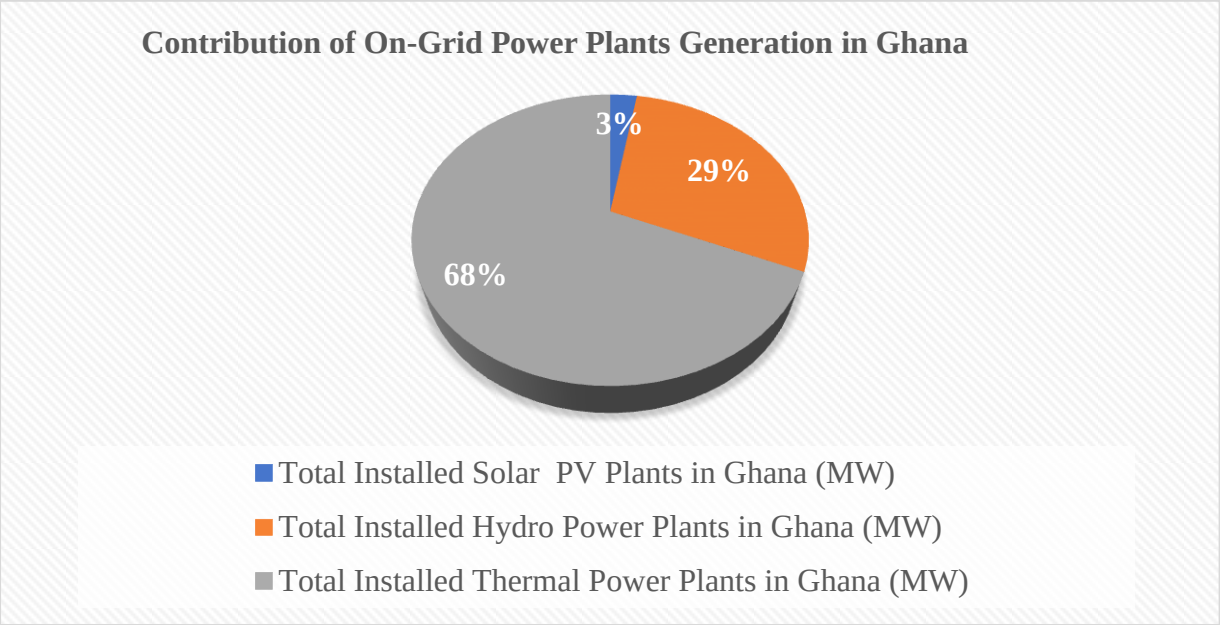

Figure 1.4: Contribution of On-Grid Power Plants Generation in Ghana

Furthermore, the environment can only be sustained if the use of fossil fuels is mitigated. The main drivers of

CO_2 are the burning of natural gas 18%, oil 31%, and coal 39% totalling 88% of global CO_2 emissions [13]. The high usage of fossil fuels is a source of concern. Therefore, there is an urgent need to take advantage of the high solar energy potential in the country to generate electrical energy to save the natural environment. Table 1.6 illustrates the emission per each generation technology in gCO_2/KWh [7]. With the dominance of fossil fuels in the generation of electrical energy globally is a matter of great concern that must be curtailed to protect the environment and the general human life. The burning of coal and oil releases more carbon emissions than that of natural gas and therefore the proposal for Ghana to generate electrical power from coal fired plant should be discouraged for the country to focus more on sustainable energy that is environmentally friendly. Solar energy from the sun is free and therefore, the government should invest more in the free energy transition and reduce the over dependance of fossil fuels for the generation of electrical energy.

Table 1.6: Carbon Emissions per each generation technology in gCO_2/KWh [14]

#	Generation Technology	Sources	gCO_2/KWh
1	Natural Gas	Combustion	400
2	Photovoltaic	Construction	100 - 200
3	Hydro		18

Currently, fossil fuel (Natural Gas) is the most dominant fuel used in electricity generation in Ghana, with the highest percentage of 68%, hydropower plant at 29%, and solar representing 3% respectively. However, climate change has caused significant losses and irremediable damage to land, freshwater, coastal, and open ocean marine ecosystems [15]. More than half of the CO_2 emissions occurred between 1750 and 2010 according to Intergovernmental Panel on Climate Change (IPCC) [16]

Climate Change is a known menace to the sustenance of this world, and some of the known means to control climate change are the use of non-carbon fuels to replace carbon fuels and the use of energy efficiency [14]. Emission levels from solar photo voltaics are far less than that of natural gas, which is currently dominating the electricity supply mix in Ghana. The country should continue to invest in solar power plants and reduce the dependence on natural gas.

5. Conclusion

The study found that Ghana has sufficient solar energy potential for electricity generation and therefore must take advantage of the situation to build more on-grid solar power to ensure energy security and environmental sustainability. Also, to serve as a quota toward Nationally Determined Contribution (NDC) and again, as a solution for United Nations Sustainable Development Goals (SDGs) number seven (7) which is to ensure clean energy and climate action. The overdependence on fossil fuels in the electricity generation mix in Ghana is very worrisome despite the call for effective climate action to include environmentally friendly energy resources to limit the adverse effects of carbon emissions on the environment. As already stated, solar energy resources could be the security for Ghana's electrical energy challenges in the present, and future energy sustainability. Therefore, an adequate preparation must be accomplished by policymakers to integrate more solar energy into

the national grid to avoid future energy deficiency that may be due to insufficient rainfall in the hydro dam and again, the country's inability to purchase fossil fuel to power the thermal plants due to price fluctuations because of the instability occasioned by the current war between Russia and Ukraine.

6. Recommendation

To ensure the development of the country's solar potential to guarantee energy security in the country, the study recommends that, the government of Ghana should create subsidies and incentives targeted purposely for solar power generation because of solar power potential in every part of the country. Again, an effective solar energy master plan should be developed only for solar energy. Future researchers are encouraged to conduct a quantitative study on the direction of solar energy resources and the part solar energy can play in the sustainable development of Ghana and West Africa.

7. limitations of the study

The authors declare no limitations to this study.

References

[1] S. A. N. and M. Y. S. (IRENA) Gauri Singh, "Ghana Renewables Readiness Assessment," *Int. Renew. Energy Agency*, no. November, pp. 1–60, 2015.

[2] E. N. Kumi, "The Electricity Situation in Ghana: Challenges and Opportunities," *CGD Policy Pap.*, no. September, p. 30, 2017, [Online]. Available: https://www.cgdev.org/ publication/electricity-situation-ghana-challenges-and-opportunities.

[3] J. J. Ramsden, "What is sustainability?," *Nanotechnol. Perceptions*, vol. 6, no. 3, pp. 179–195, 2010, doi: 10.4024/N14RA10A.ntp.06.03.

[4] M. A. Nyasapoh, S. K. Debrah, D. K. Twerefou, S. Gyamfi, and F. K. Kholi, "Review Article An Overview of Energy Resources and Future Concerns for Ghana . s Electricity Generation Mix," vol. 2022, 2022.

[5] IRENA, "World energy transitions outlook," *Irena*, pp. 1–54, 2021, [Online]. Available: https://irena.org/publications/2021/March/World-Energy-Transitions-Outlook.

[6] Ghana Energy Commission, "National Energy Statistics 2007 - 2016," *Annu. Energy Rep.*, vol. 2016, pp. 1–40, 2017.

[7] C. Kuamoah, "Renewable Energy Deployment in Ghana: The Hype, Hope and Reality," *Insight on Africa*, vol. 12, no. 1, pp. 45–64, 2020, doi: 10.1177/0975087819898581.

[8] E. C. Ministry of Energy, "Ghana Renewable Energy Master Plan," *Ghana Renew. Energy Master*

Plan, 2019.

[9] Energy Commission, *2021 National Energy Statistics*, no. April. 2021.

[10] Ministry of Energy, "National Energy Policy: Republic of Ghana," no. February, pp. 1–30, 2010, [Online]. Available: http://www.petrocom.gov.gh/assets/national_energy_policy.pdf.

[11] Ministry of Energy, Energy Commission, Ministry of Science and Technology of China, and UNDP, "Ghana Renewable Energy Master Plan," *Ghana Renew. Energy Master Plan*, pp. 1–83, 2019.

[12] E. N. Kumi, "Challenges and Opportunities CGD Policy Paper, 109 September 2017," *Cent. Glob. Dev.*, no. September, 2017.

[13] J. G. Olivier and J. A. H. W. Peters, "Trends in Global CO2 and Total Greenhouse Gas Emissions," *PBL Netherlands Environ. Assess. Agency*, vol. 2020, no. February, p. 70, 2020, [Online]. Available: www.pbl.nl/en.

[14] M. Steen, "a At T Ti I Io O on N N S Sy Ys S St T E Em M E S E S E E E Eur 19754 En," [Online]. Available: http://www.jrc.nl.

[15] R. B. Hans-O. Pörtner , Debra C. Roberts, Helen Adams, Carolina Adler, Paulina Aldunce, Elham Ali, Rawshan Ara Begum, *Climate Change 2022 - Impacts, Adaptation and Vulnerability - Summary for Policymakers*. 2022.

[16] M. Jarraud and A. Steiner, "Summary for policymakers," *Manag. Risk Extrem. Event Disasters for Adv. Clim. Chang. Adapt. Spec. Rep. Intergov. Panel Clim. Chang.*, vol. 9781107025, pp. 3–22, 2012, doi: 10.1017/CBO9781139177245.003.