Energy and Policy Research

ISSN: (Print) 2381-5639 (Online) Journal homepage: https://www.tandfonline.com/loi/uetp21

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To cite this article: E. O. Diemuodeke, A. Addo, I. Dabipi-Kalio, C. O. C. Oko & Y. Mulugetta (2017) Domestic energy demand assessment of coastline rural communities with solar electrification, Energy and Policy Research, 4:1, 1-9, DOI: 10.1080/23815639.2017.1280431

To link to this article: https://doi.org/10.1080/23815639.2017.1280431

Published online: 21 Feb 2017.

ENERGY AND POLICY RESEARCH
2017, VOL. 4, NO. 1, 1–9
http://dx.doi.org/10.1080/23815639.2017.1280431

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Domestic energy demand assessment of coastline rural communities with solar electrification

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ABSTRACT
The coastline rural communities in the Niger Delta region of Nigeria have long suffered from the consequences of poor rural electrification, environmental degradation, and health challenges. There is an urgent need to provide an optimal sustainable and environment-friendly energy system for the coastline rural communities in Nigeria, which has the potential of ameliorating the climate change in this country. The HOMER hybrid optimization software and the estimated domestic energy demand of the coastline rural communities were used to determine the best PV solar energy system. The NASA SEE database with monthly averaged values for global horizontal radiation over a 22-year period was considered in the current analysis. The daily energy demand of a typical household in the communities was estimated for the existing energy demand (EED), future electric energy demand (FEED), and future base energy demand (FBED) scenarios as 5.640, 8.830, and 7.233 kWh, respectively. The suggested best energy system has a cost of electricity of 0.651, 0.653, and 0.674 $/kWh for the EED, FEED, and FBED, respectively. The best energy system gives the best components with an appropriate operating strategy to provide an efficient, reliable, cost-effective, and environment-friendly system. It is shown that both positive energy policies of the Federal Government of Nigeria toward renewable energy penetration and the support from the oil-producing companies toward their operational areas would see the cost of electricity being significantly reduced. It is envisaged that the implementation of the suggested energy system with other environmentally responsible interventions would support the Niger-Delta's coastline rural communities, whose livelihoods have been impaired by gas and oil exploration, to attain their full environmental and socioeconomic potentials.

ARTICLE HISTORY
Received August 2016
Accepted December 2016

KEYWORDS
Coastline rural communities; renewable energy; energy demand; solar PV; economic; environment; HOMER software

1. Introduction

It has been reported that the global demand for primary energy is on the steady increase, and if the demand is maintained at a conservative average rate of 2%, the total global energy demand would increase by 100% in the next three decades.[1] Therefore, there is a need for a strong motivation to implement a more sustainable energy mix globally—driven by positive polices and commitments. More so, there is a concern by the international development agencies—namely, the United Nation Development Programme (UNDP), the Africa Development Bank (AfDB), the World Bank, the Global Environmental Facility (GEF), the Africa Renewable Energy Fund (ARDF), and so on—and regional and national governments to provide electricity to about 16% of the world population living without electricity in rural communities.[2] A possible solution to the energy starvation of rural areas, especially the coastline communities, would be the deployment of a distributed energy project through the utilization of renewable energy sources, as the majority of coastline rural communities are a dispersed population with relatively low energy demand.

It has been reported that 1.2 billion people are currently living without electricity globally, and about 95% of the people living without electricity are concentrated in sub-Saharan Africa and the developing nations in Asia. The global population living without electricity are mainly in the rural areas—about 80% of the world population living without electricity.[2] It is estimated that only about 40% of the population of Nigeria has access to the national grid, with electricity supply reliability of about 40%[3]; and 6% of the population with access to the national grid has a diesel generator to augment supply from the national grid—more than 45% of the total households have no access to electricity in the country.[4,5,6] This is an abysmal electricity supply considering the fact that the per capita electricity consumption in Nigeria is four times less than the African average, and about 19 times less than the global average.[2,4] Nigeria is located on the west coast of Africa, with a projected population of about 180 million people. Nigeria occupies an important position in the sub-Saharan Africa in terms of primary energy supply, population, economy, and politics. Nigeria covers a 923,770 km^2 geographical area, of which total land area is 910,770 km^2, with an 853 km^2 approximate coastline area. The South-South (SS) geopolitical zone, which houses six states (Akwa-Ibom, Bayelsa, Cross-River, Edo, Delta, and Rivers) of the 36 states of Nigeria, is one of the six geopolitical zones in the country. More than 90% of the political Niger-Delta region is occupied by the SS geopolitical zone. The SS geopolitical zone is

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rich in both renewable and nonrenewable natural resources—a large proportion of Nigeria's oil and gas reserves and production is from the zone. A significant proportion of Nigeria's coastline is in the SS geopolitical zone. The coastline areas have dispersed settlements located mainly in rugged terrain.

The coastline communities, besides the environmental degradation and health concerns, usually lack in roads, running water, and, ultimately, electricity supply. The grossly inadequate supply of electricity has left the communities underdeveloped—socially and economically. As the coastline areas have dispersed settlements located mainly in rugged terrain, and coupled with the privatization of the power sector, this makes their electricity supply economically impossible (at least in the next decade)—in spite of the region's large daily production of oil and gas. Meanwhile, electricity is required for such basic developmental services such as pipe-borne water, health care, telecommunications, and quality education.[7] Furthermore, the poverty eradication and universal basic education programs of the Federal Government of Nigeria (FGN), which are targeted at the rural communities, need electricity to be successful. The absence of the electricity supply from the national grid not only has left the communities socially backward but has left their economic potentials unexploited,[8] which is substantiated by the fact that qualitative and quantitative energy systems are important to sustainable national development and poverty alleviation.[9,10]

The pump prices of petroleum products in the coastline rural communities are normally above the official pump prices worldwide, seemingly due to their dispersed settlement, remote location, rugged terrains, and inaccessible road networks.[11,12] A significant number of Nigeria's coastline communities depend totally on diesel generators and firewood to meet energy needs.[5] This implies that the combined effect of stringent government policy against indiscriminate deforestation and total deregulation of the petroleum downstream sector would have an undesirable impact on the social-economic situation of the communities. The Nigerian Ministry of Power has identified the utilization of renewable energy technologies in the FGN's energy mix as a possible means of curbing the energy and power crisis and climate change bedeviling the country.[3] Moreover, the trend in energy utilization worldwide is toward drastic reduction in dependence on the depleting, expensive, and environment-unfriendly fossil fuels.[3,13–18] Their utilization has an adverse impact on the environment, such as their global warming potential (GWP) and greenhouse gas (GHG) emissions, which normally lead to many negative effects, including climate change, receding of glaciers, rise in sea levels, and loss of biodiversity. The life cycle analysis (LCA) of the Nigerian electricity sector has shown that the sector's activities have caused a significant environmental impact, which is strongly associated with the overwhelming use of the fossil fuels in the energy mix.[19] The environmental impact is expected to be more significant with the continuous utilization of absolute fossil-fuel-driven energy systems, especially in the coastline rural communities that rely on firewood and diesel generators to meet their energy needs.

Currently, there is much support for the deployment of renewable energy in many developing nations, namely China, India, South Africa, Algeria, and Senegal, among others.[7,13,20] However, there is a strong need to conduct research that explores the best energy alternatives that match the energy demand of a given locality to facilitate the significant penetration of renewable energy technologies in the energy mix. Therefore, renewable energy technologies (RETs) as alternative or complementary energy sources in these coastline rural communities would be of great benefit, especially the attendant concerns for climate change as a result of conventional energy conversion technologies, which play important roles in the general acceptance of RETs. The search for the optimal storage of the harnessed energy from renewable energy sources is paramount, since the supply of renewable energy is transient. Integrating RETs with storage systems would provide reliable and secured clean energy supply. Many research works have been devoted to RETs with battery energy storage systems for rural communities.[21–23] The majority of the RETs are not absolutely environment-friendly, since they consider diesel generator in the hybridization. Therefore, the driving force for this present work is the exploration of alternative distributed energy systems for the coastline rural communities, which is based on solar PV energy utilization, to energize the socioeconomic potentials of the coastline rural communities and to ameliorate the effects of climate change bedeviling the communities. Distributed energy systems are decentralized energy generation facilities that satisfy localized energy demands. These systems principally use renewable energy sources but may also have a fossil fuel element in the energy mix. The generated energy reaches the consumers through smaller transmission grids known as microgrids, which are cheaper and more easily maintained.

2. Materials and methods

The design of efficient and reliable RETs is dependent on the energy demand of the intended facility, location of the facility, renewable energy resource availability, and economic considerations.

2.1. Estimation of household energy demand

The estimation of an hourly energy demand (energy demand profile) of a given facility is paramount in the sizing of an optimal renewable energy system, since the renewable energy sources are normally transient in supply. This is the first attempt to conduct energy demand for the entire coastline rural communities in the Niger Delta region of Nigeria.

2.1.1. Data collection

Appropriate questionnaires were designed to capture all the aspects of energy consumption and basic family background of a given household. Community visitations and interviews were undertaken to assess the existing and future electrical energy demand of representative coastline communities. The interviews were conducted both in person and by phone (phone interview became necessary due to security challenges within some of the selected communities).

Within the sampled area, 12 coastline communities (two communities from each state) were systematically chosen to cover the whole six states in the SS geopolitical region. The two communities selected from each of the six states feature the existing electrical energy demand scenario and the attributes of a future electric energy demand scenario. The candidate coastline rural communities for the "existing energy demand (EED)" have diesel generating sets, whereas the candidate communities for "future electric energy demand (FEED)" have a 24-hour supply of electricity from the oil-producing companies' facilities (e.g., field logistic base). Twenty households were randomly selected from each of the 12 candidate coastline rural communities (totaling 240 coastline rural households).

The featured households' energy demand appliances are ceiling fan, table fan, TV, portable stereo, fluorescent light, CD player, pressing iron, A/C, microwave, washing machine, and others. The current estimation included all appliances used in the coastline rural communities to ascertain the actual energy requirements of the households; this is a clear departure from a similar work conducted by Adeoti et al.[6] for the Southwest geopolitical zone.

2.1.2. Data analysis

The average hourly electric load requirement of an appliance per household in a given day, E_{kj} (Wh/household/day), can be computed by Equation 1. Equation 1 is independently used for the EED and FEED scenarios.

$$E_{kj} = \frac{\sum_i^{N_H} p_{ij}^k}{N_H}; j = 0, 1, 2, \ldots, 23 \tag{1}$$

where P(kW) is the power consumed by an appliance in a given hour, N_H is the total number of households, k is a superscript representing an appliance, i is the current household, and j is the hour of the day.

The average hourly energy demand per household per day, E_{kj} (Wh/household/day), is computed by

$$E_j = \sum_k^A E_{kj}; j = 0, 1, 2, \ldots, 23 \tag{2}$$

where A is the total number of appliances.

The average daily energy requirement, E_{de} (kWh/household/day), can be obtained by Equation 3:

$$E_{de}^m = \sum_{j=0}^{23} E_j; m \in \{EEL, FEED\} \tag{3}$$

The average of EED and FEED energy demand scenarios, which may be taken as the future base energy demand (FBED), can be expressed as

$$E_A = \frac{E_{de}^{EEL} + E_{de}^{FEED}}{2} \tag{4}$$

2.2. Resource assessment

Solar energy is generally harnessed for photovoltaic and thermal applications. The main factor influencing the economic performance of a solar energy system is the available solar irradiance that could be harnessed for heat and electricity generation. Solar irradiance is the amount of energy from the sun that hits a unit area in a given time interval; its unit is in Wh/m^2. [24] There are, normally, three basic approaches available for the estimation of solar irradiance on flat surfaces—the estimation based on in situ data; the estimation based on satellite data; and the combination of in situ data and satellite data. The estimation based on geostationary satellite data have been deployed in many applications.[25,26] Specifically, the experimental data presented in the literature confirms the applicability of the NASA Surface Meteorology and Solar Energy (SSE) data for the African continent.[27] Therefore, the NASA SEE database about global horizontal radiation that monthly averaged values over a 22-year period (July 1983–June 2005) was considered in the current analysis.[28]

2.3. Economic analysis

The cost of electricity from a solar PV system—which, normally, comprises a PV panel, battery bank, and converter—is dependent on the annualized life cycle cost (ALCC) of the solar PV system.[29,30] The life cycle cost (LCC) of an item, expressed as the present worth, is dependent on the total cost of acquiring and operating the item over its lifetime. The costs of a solar PV system include acquisition costs, operating costs, maintenance costs, and replacement costs. The maintenance and operating costs are relatively low for a localized solar PV energy system.[31,32] The present worth analysis is a function of the prevailing discount rate and depreciation of 13% and 9.4%, respectively, as used in the literature for Nigeria.[19] All the basic economic calculations are appended in the HOMER software computational algorithm. Therefore, the HOMER, which stands for Hybrid Optimization Model for Electric Renewable, is adopted for the current analysis. The National Renewable Energy Laboratory of the USA developed the HOMER software for both grid-tied and stand-alone applications. Optimization and sensitivity computational algorithms of the HOMER software allow the rapid and robust techno-economic evaluations of various energy technology options by accounting for the cost of energy alternatives and availability of renewable energy resources. The HOMER uses the load demand, the resources, the components details (with costs), the constraints, the systems control, and the emission data as an input to simulate various feasible configurations and rank by the net present cost (NPC).[33]

3. Results and discussion

3.1. Energy demand per household in coastline rural communities

Figures 1 and 2, respectively, present the estimated daily average energy demand profiles per household for the EED and FEED scenarios. Figure 1 is a representation of the current electric energy demand profile per household in the coastline rural communities in the geographical Niger Delta of Nigeria (the SS geopolitical zone). The figure shows that between the hours of 1:00 hour and 5:00 hours, there is no energy demand, which is attributed to no supply of electricity as the general community diesel-generating set

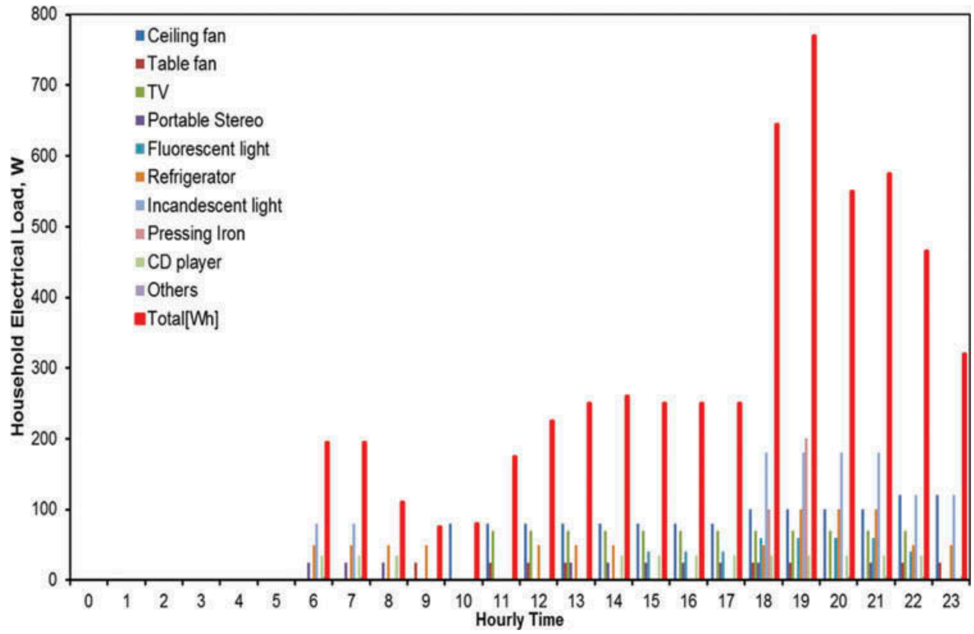

Figure 1. Household energy demand profile for EED scenario.

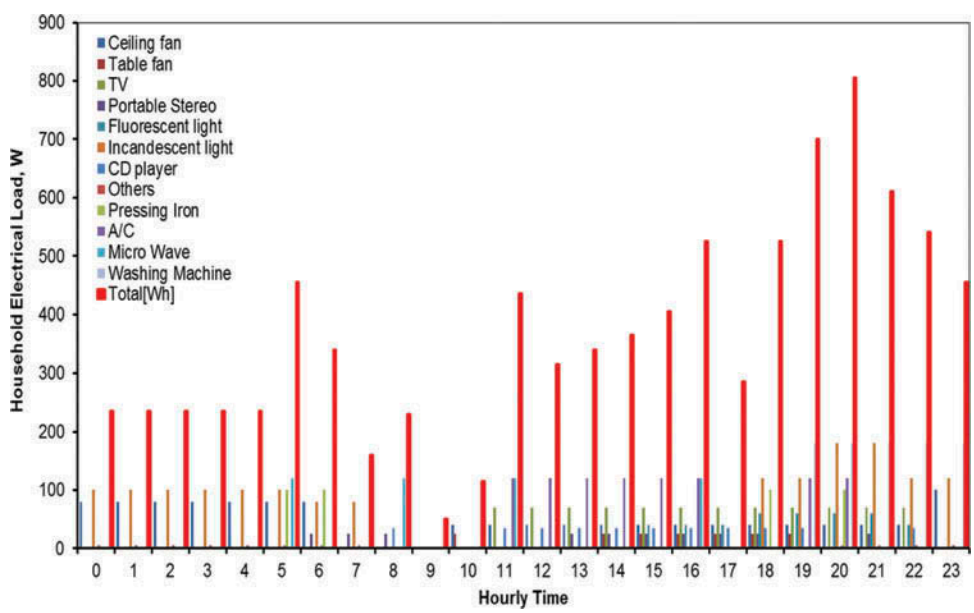

Figure 2. Household energy demand profile for FEED scenario.

works on average between 18:00 hours and 23:00 hours daily. The sudden rise in energy demand between 6:00 hours and 7:00 hours is associated with the morning activities in preparation for work and school. It is observed that the demand is low within the hours of 8:00 hours to 10:00 hours, and this can be explained by the fact that most people are out of the house for their daily activities during this period. Furthermore, the energy demand between 11:00 hours and 17:00 hours is attributed to the power demand for operation of business shops; the demand is normally met by individual petrol-generating sets. Finally, between 18:00 hours and 23:00 hours the electricity demand is high because virtually all the members of the household are back home and make use of electricity for various domestic loads specified in the figure.

Figure 2 represents a typical FEED profile per household in the coastline rural communities. The figure shows that between the hours of 1:00 and 4:00, there is a constant energy demand associated with lighting power requirements during the night sleep. There is no zero energy demand associated with the FEED scenario, as there is a constant electricity supply. The profile between 5:00 hours and 23:00 hours could be explained as in the EED scenario.

Figure 3 represents the average of the EED and FEED scenarios. This profile could represent the future base energy

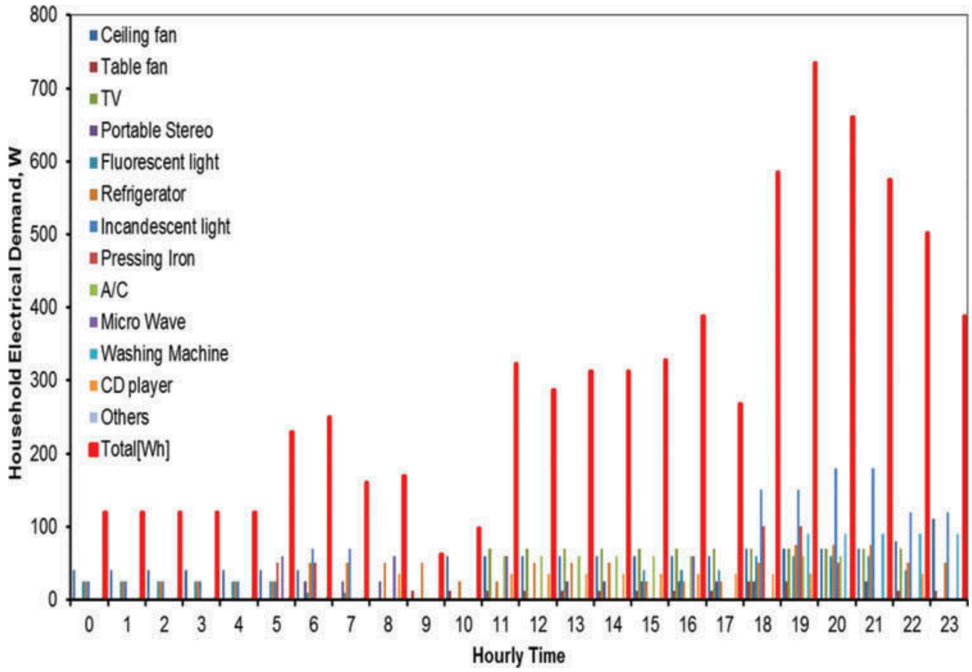

Figure 3. Average of EED and FEED energy demand.

demand (FBED). The explanation of this energy profile could be extrapolated from the EED and FEED scenarios.

Table 1 presents the results of the daily energy demands, Equations 3 and 4, of the three scenarios of households' energy demand surveyed. From the table, it can be seen that the existing energy demand is 5.640 kWh/day or 2,058.6 kWh/year; the future energy demand would be 8.830 kWh/day or 3,222.95 kWh/year, and the future base energy demand would be 7.233 kWh/day or 2,640.05 kWh/year. The factors responsible for the highest energy demand of households with access to a 24-hour electricity (the FEED) could be attributed to: (1) the use of more appliances; (2) the use of higher power rating appliances (e.g., A/C, washing machine, microwave); or (3) the long duration appliances are put to use. However, proper optimization of the energy use of the households (use of low-energy bulbs, for example) would see the future energy demand being reduced, which may compensate for the possible rise in the future energy demand scenario as a result of an improved standard of living.[34]

It can be shown from Table 1 that the SS zone requires 537 kWh of electricity per capita per year in the future for a sustainable development, which is about four times more than the 2015 estimation for Nigeria.[35] It should be noted that the SS zone has a high taste for modern electrical appliances due to the economic and social interactions with the oil and gas production activities in the region.

Table 1. Total energy demand.

	EED	FEED	FBED
Energy demand/household/day [kWh/household/day]	5.640	8.830	7.233
Energy demand/Capita/year [kWh/Capita/year]	343.10	537.16	440.00

3.2. Solar irradiance

Figure 4 represents the monthly average solar irradiance of the selected sites in the six states of the SS geopolitical zone, which is based on the NASA SEE database, which has been shown to be adequate for the African continent.[27] On average, the solar irradiance is low between the months of May and October, which are associated with the raining season. The solar irradiation is highest between the months of January and March, which are associated with the dry season. The month of April, with average solar irradiance, is a transition month between the dry season and the rainy season. The months of November and December, which are associated with the Harmattan season usually experienced by the tropical rainforest (or the equatorial monsoon) that the SS geopolitical zone belongs to, feature moderately high solar irradiance. The data in Figure 4 serve as input data for the techno-economic analysis of the solar PV energy system.

3.3. Economic and environmental analyses

The technical and economic specifications used for the economic and environmental analysis are presented in Table 2.

Table 3 presents the computed results for the techno-economic analysis, which is based on Figures 1, 2, 3, 4 and Table 2. It is shown that in all three scenarios (EED, FEED, and FBED), Akwa-Ibom State has the lowest cost of electricity (COE) and initial capital cost of investment, which can be attributed to the relative high annual averaged solar irradiance of 4.71 kWh/m^2/day. It is also shown that the EED scenario has the lowest initial cost of investment and highest cost of unit electricity, which could be attributed to the lowest energy demand and the requirement for a high volume of battery bank to store energy against the peak demand at night,

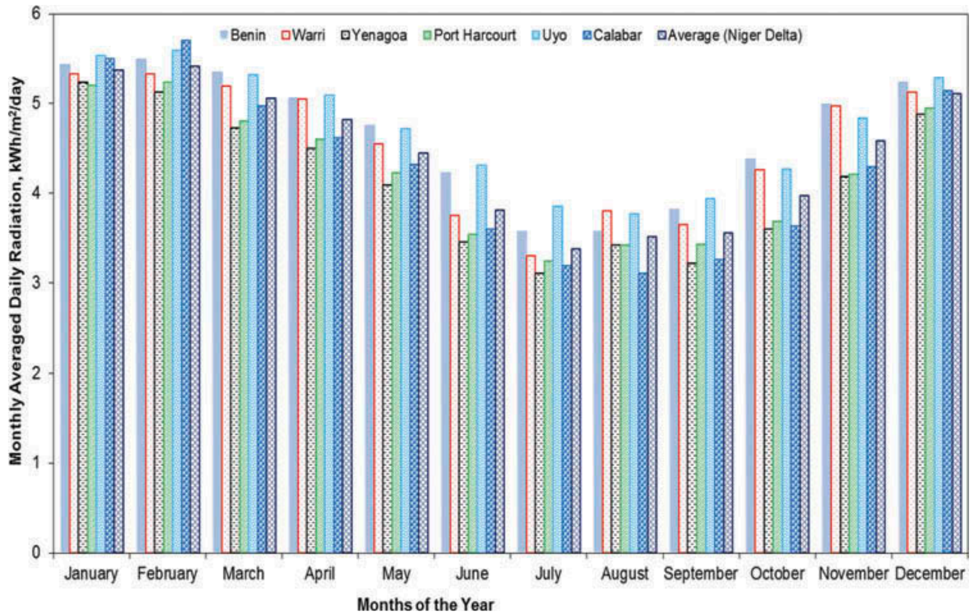

Figure 4. Solar irradiance of selected sites in the SS zone.[28]

Table 2. Technical and economic specifications.

No.	Description	Specification
1	Generic flat-plate PV panel	
	Capital cost [$/kW]	2500.00
	Replacement cost [$/kW]	2350.25
	Maintenance cost [$/kW/year]	0*
	Lifetime [years]	25
2	Auto size Genset	
	Fuel	Diesel
	Fuel cost [$/liter]	1.00
	Capital cost [$/kW]	500.00
	Replacement cost [$/kW]	500.00
	Maintenance cost [$/kW/hr]	0.03
	Lifetime [hours]	15000
3	System converter	
	Capital cost [$/kW]	300.00
	Replacement cost [$/kW]	300.00
	Maintenance cost [$/kW/year]	100.00
	Lifetime [years]	15
4	Generic 1 kWh lead acid battery	
	Capital cost [$/battery]	300.00
	Replacement cost [$/battery]	240.00
	Maintenance cost [$/kW/year]	10.00
	Lifetime [years]	10

*This value is based on the assumption that the operating and maintenance cost is negligible for a localized distributed energy systems.[31,32]

respectively. It can be shown from Table 3 that a household in the SS zone is expected to pay average of $0.651 for a unit of electricity (kWh) consumed in the EED scenario, which is expected to increase by 0.31% for the FEED.

The COE obtained is not economically competitive with the current average COE of 0.091 $/kWh from the country's national utility grid, which is predicated on the ground that there is a zero cost of extending the national grid to the coastline rural communities.[36] However, it is shown in Figure 5 that positive economic policies of the FGN toward renewable energy penetration, for example, special interest rate for renewable energy projects, would see the COE being reduced. The figure suggests that reducing the discount rate to 8% would put the COE at 0.489 $/kWh for the future energy demand scenario in the SS zone.

Furthermore, the support from oil-producing companies toward the development of their operational areas, for example, subsidizing renewable energy conversion technology components, would see the COE being reduced. This argument is supported by Figure 6. The figure suggests that the cost of unit electricity decreases with decreasing solar PV cost, which can be attributed to the corresponding reduction in the annualized cost of the entire solar PV system. This observation is expected to be the same for the other two scenarios. The figure shows that a reduction of only the solar PV cost for the FEED scenario by 50% would reduce the COE and the initial cost of investment to 0.52 $/kWh and $13,306, respectively. Therefore, both positive attitudes of the FGN and

Table 3. Computed econometric data.*

			EED		FEED		FBED	
State	Location	Annual averaged solar irradiance (kWh/m^2/day)	Initial cost ($)	COE ($/kWh)	Initial cost ($)	COE ($/kWh)	Initial cost ($)	COE ($/kWh)
Akwa-Ibom	5°20.3′N,7°54.8′E	4.71	11,768	0.626	18,191	0.623	14,669	0.611
Bayelsa	5°00.7′N,6°40.6′E	4.13	13,773	0.691	21,144	0.683	18,033	0.705
Cross-River	4°33.5′N,7°57.6′E	4.28	14,008	0.706	20804	0.677	17,855	0.703
Delta	5°33.3′N,5°47.6′E	4.53	12,687	0.658	19,355	0.646	15,941	0.643
Edo	6°20.1′N,5°36.2′E	4.66	12,106	0.638	18,560	0.630	15,050	0.621
Rivers	4°48.9′N,7°30.3′E	4.21	13,974	0.704	21,170	0.688	18,151	0.708
SS Zone*	4°35.6′N,6°42.6′E	4.42	12,608	0.651	19,715	0.653	16,809	0.674

*Computation is based on the average of solar irradiance of the states considered.

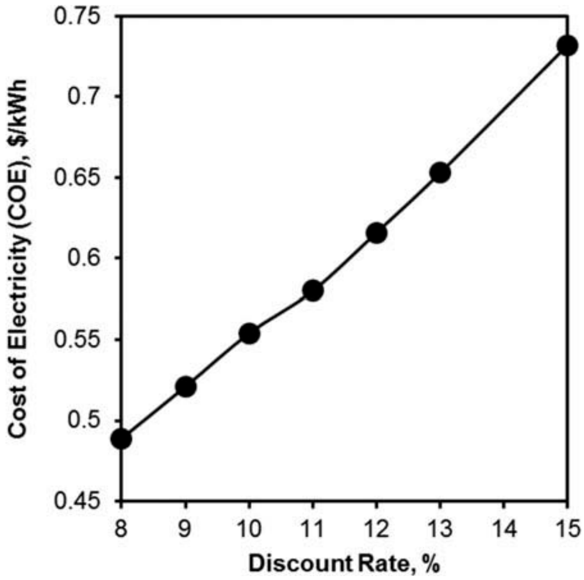

Figure 5. Variation of COE with discount rate for FED in SS zone.

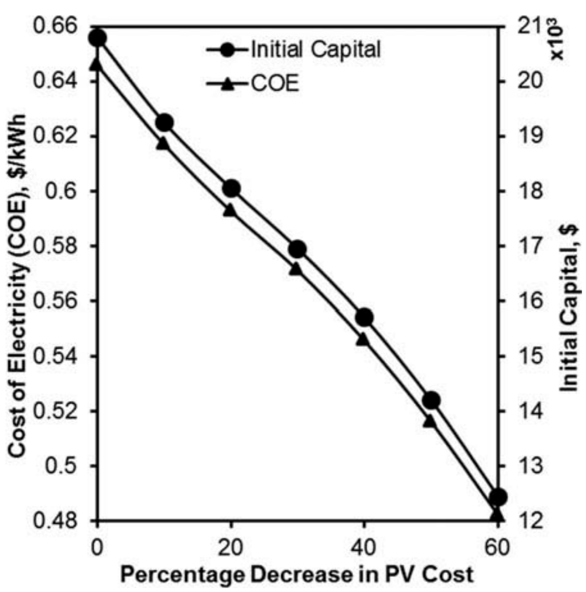

Figure 6. Variation of COE and initial capital with PV cost for FED in SS zone.

oil-producing companies toward the utilization of RETs in the coastline rural communities would see a significant reduction in the COE, which would make it economically attractive.

The environmental degradation within the SS zone is extremely significant, and it is attributed to the oil and gas production activities, the heavy reliance on diesel generator for electricity supply, and the use of firewood for heating needs. The solar PV energy system has the potential of reducing environmental impact caused by the diesel generators for energy needs, as shown in Figure 7. The figure suggests that the current use of generators to meet energy demand generates 3,442 kg/household/year of CO_2, and that the continuous use of solely diesel generators to meet future energy demand could harm the environment by huge emissions of CO_2 to the amount of 5,119 kg/household/year, which is about 148.7%/year of the existing emissions. For example, a typical coastline community with 200 households has the potential of generating 1,023,800 kg/year of CO_2 in the future (the FEED scenario) with absolute reliance on the diesel generators for a power supply. Moreover, the use of diesel generators is not economically viable—for example, the cost of unit electricity for the future energy demand would stand at 0.886 $/kWh, which is 35.68% more of the solar PV energy system. The utilization of solar PV would absolutely eliminate CO_2 emissions, which would make the environment friendlier. It is expected that the reduction in GWP due to the elimination of CO_2 from diesel generators would equally manifest in the reduction of other environmental impacts, namely abiotic depletion, ozone depletion potential, human toxicity, freshwater aquatic ecotoxicity, marine aquatic ecotoxicity, terrestrial ecotoxicity, photochemical oxidation, acidification, and eutrophication.[19]

A palliative measure to make the SS zone environment friendlier is by considering the use of a generator-battery tied energy system, which has the potential of reducing emissions by 11.16% for a future energy demand scenario, as shown in Figure 7, since the initial cost of investment of diesel generators is relatively low. However, COE of the generator-battery tied energy system is inferior compared to the solar PV energy system.

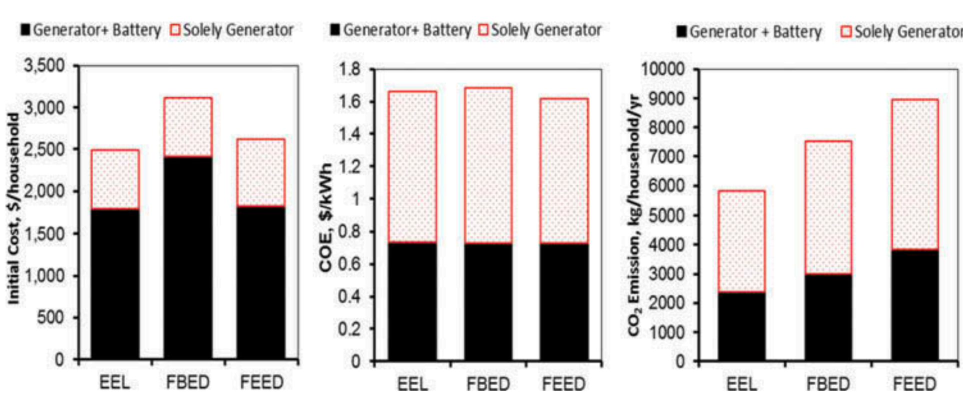

Figure 7. Economic-environmental parameters under diesel generators.

4. Conclusion

There is much support for the deployment of RETs in many developing nations, namely China, India, South Africa, Algeria, and Senegal; however, there is a strong need to conduct research that explores the best alternatives that match the local energy demand to facilitate significant penetration of renewable energy in the energy mix. The deployment of RETs as alternative or complementary energy sources in these coastline communities would be of great benefit, which has the potentials of ameliorating the effects of climate change in the coastline regions. Therefore, there is an urgent need to provide an optimal sustainable and environment-friendly energy system for the coastline communities in Nigeria. The design of efficient and reliable renewable energy systems is dependent on the well-established energy demand of the facility, the location of the facility, the renewable energy resource availability, and the economic considerations. The HOMER hybrid optimization software and the estimated domestic energy demand of the coastline rural communities were used to determine the best PV solar energy system. The NASA SEE database about the monthly average values for global horizontal radiation over a 22-year period (July 1983–June 2005) was considered in the current analysis. The daily energy demand of a typical household in the communities was estimated for the existing energy demand (EED), the future electric energy demand (FEED), and the future base energy demand (FBED) scenarios, respectively, as 5.640, 8.830, and 7.233 kWh. The suggested best hybrid energy system has a cost of electricity of 0.651, 0.653, and 0.674 $/kWh for the EED, the FEED, and the FBED, respectively. The best energy system gives the best components with an appropriate operating strategy to provide an efficient, reliable, cost-effective, and environment-friendly system. It is shown that both positive energy policies of the Federal Government of Nigeria toward renewable energy penetration and the support from oil-producing companies toward their operational areas would see the cost of electricity being significantly reduced. It is envisaged that the implementation of the suggested energy system with other environmentally responsible interventions would support the Niger Delta coastline communities, whose livelihoods have been impaired by gas and oil exploration, to attain their full environmental and socioeconomic potential. The environment-friendliness of utilizing the solar PV energy system against the existing diesel generators in the coastline communities is quantitatively evaluated. Reducing fossil-fuel-driven energy sources in the coastline communities, which are concentrated mainly in the Niger Delta region of Nigeria, not only would reduce the environmental impacts but also would contribute to the socioeconomic advancement of the downtrodden coastline communities.[37,38] It is expected that the sustainable energy system here presented could be replicated globally in the coastline rural communities once the prevailing renewable energy source is determined.

The move by the FGN to radically increase the grid capacity to 25,000 MW by 2025,[19] if realized, may not even favor the extension of the national grid to the coastline communities due to rugged terrains and the privatization of the power sector that is profit driven.

Funding

This work was supported under the CIRCLE Visiting Fellowship program funded by the UK Department for International Development. Neither the findings nor the views expressed, however, necessarily reflect the policies of the UK government.

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