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Development of an Intelligent Smart Hub Renewable Generation System (ISHRGS) for both Urban and Rural Centres in Offa, Kwara State

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Intelligent smart grids combine the generation, storage and consumption of energy systems. The opportunities to generate renewable energy from wind, solar and hydropower are generally higher in rural areas than in cities. The future development of the energy system is based on the planning and management of the distribution grid according to the Smart Hub (SH) component. This study comprehensively reviews the accessibility to the generation of electricity and the accessibility of renewable generation systems in urban and rural centres in Offa. It also examines the potential of an intelligent smart hub renewable generation system (ISHRGS) resources in Offa, Kwara State, that harnesses continuous energy supply and sustainability. Therefore, the historical background of the energy distribution in Offa, which led to this approach, is briefly presented with a comprehensive schematic diagram. Using a typical hypothetical example, modelling different components of SH and using them together to optimize ISHRGS using a genetic algorithm is presented. However, the study compares ISHRGS to different rural development approaches based on the feature of high adaptability to meet the temporal needs efficiently, and the parts reflect the intelligent character of the smart hub concerning electricity demand in the region.

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1. INTRODUCTION

Electricity is essential; without electrification, a human being cannot access important parts of society. Infrastructure and information technologies improved the education level of an area. Health services in clinics and hospitals rely on electricity, such as persevered medicine, emergency treatment or night time care. Business activities and manufacturing and service sectors are enabled and enhanced. Poverty eradication and women empowerment are also positively affected by access to electricity. Therefore, globally the right to access electricity is getting more recognised. Nevertheless, worldwide more than 1 million people lived without electricity in 2016. That is about 14% of the world's population [1].

The most affected are the rural areas of developing countries. In total, 84% of those without access to electricity are rural dwellers. In rural and remote locations in developing countries, the connection to the centralised grid system is often hindered by complex terrain, high investment costs and low power demand. Moreover, centralised power plants often run on fossil fuels and are therefore highly unsustainable. In remote places, an intelligent smart hub renewable generation system can be the most convenient and sometimes even the option to generate and supply clean electricity to urban and local communities [1,2]. There are four main ways to generate distributed renewable electricity: small hydropower that respects the ecology of rivers, small wind power, small photovoltaics, small biomass systems, using human and agricultural waste or wood gas technology, or a combination of those, so-called Hybrid Systems (HS). Distributive renewable electricity systems can either work off-grid or be connected to mini-grid. Mini-grid systems are centralised power networks that transmit electricity to the demand area.

They usually use battery backup. For example, the energy supply in a remote town is sometimes even connected to neighbouring towns. Off-grid, or stand-alone systems, are not linked to any grid. The stand-alone systems power households or businesses, where all electricity is consumed on-site or very close by, the development of intelligent smart hub renewable generation systems is often hindered by policy uncertainty in national strategies and regulations and a lack of financial resources. However, an intelligent smart hub renewable generation system can be developed in the mid-term. Depending on urban and rural situations, they can be more cost-effective than centralised systems. They benefit from modularity, adaptability to specific local conditions and low environmental impacts. Intelligent Smart Hub Renewable Generation System ISHRGS is a Smart Energy Hub is a hybrid power storage/cogeneration system that uses hydrogen vector and effectiveness offers an unprecedented opportunity to accelerate access to electricity. The access to electricity can properly development and implementation of those systems can improve the livelihood of billions worldwide [2].

It is easy to take electricity for granted, but modern life cannot be possible with it. An intelligent smart hub renewable generation system is necessary to manage electricity [2]. For over 500 years, coal and other fossil fuels have been used by power plants to generate electricity use every day. The grid is a network of power lines and sub-station that carry electricity from power plants to homes and businesses. According to Chen [3], the problem today in grid networks is complexity and upgrades. When the power line breaks or is unable to produce enough electricity, blanking out can occur, becoming a significant problem [3]. Today's grid often relies on a single power source and does not reveal detailed usage information. This makes electricity challenging to manage. To address the problem in the past, the demand for the development of ISHRGS in Offa city and work toward sustainability to reduce the purchasing power of fossil fuel by using a smart hub. Using a smart hub implies introducing sensors like weather stations, comparator, pressure sensors, temperature sensors, humidity sensors, , current sensors, and voltage sensors and relative software which includes Smart meter maker, energy management, mart meter networking and communications provider, grid automation software and many more in existing grid that will give utility to individual new information that will help to understand on react to changes quickly.

2. PERIODICAL PEAK LEVEL OF ELECTRICITY SUPPLY AND THE DISTRIBUTION MULTISOURCE

An instance of a tree falling on a power line makeover 1000 homes out of electricity supply. It takes much time for electric power distribution to reroute power manually, but with the smart hub, sensors and software will detect and immediately reroute the power around the problem leaving power to few homes [4]. The power of electricity changes daily, as shown in Fig. 1. This is seen on consumer meters at every home. At times may be expensive during day time and cheap at the night time. Electricity consumers can decide to run powerful electronics gadgets when the power is cheap as shown in Fig. 1 and Fig. 2. This prevents outrageous electricity bills and safe blank out at peak hours. Hence, the smart hub also means a new way to use renewable energy [4]. Power generation can be distributed across multiple sources, making the system more stable and efficient. According to Bertolini [4] study investigate the inability to communicate and manage electricity, make the grid more innovative and also help the burning of more fossil in the future see Fig. 3.

The smart hub is more initiative behind the sustainability of electrification in the city of Offa, and the community is concerned with the adequacy of power generation. The sustainable development power needed to be developed in Offa city to manage electricity bills and efficiently help rural and urban environments. It will be a great relief to the country's economy by making an informed decision on how to use electricity in every home.

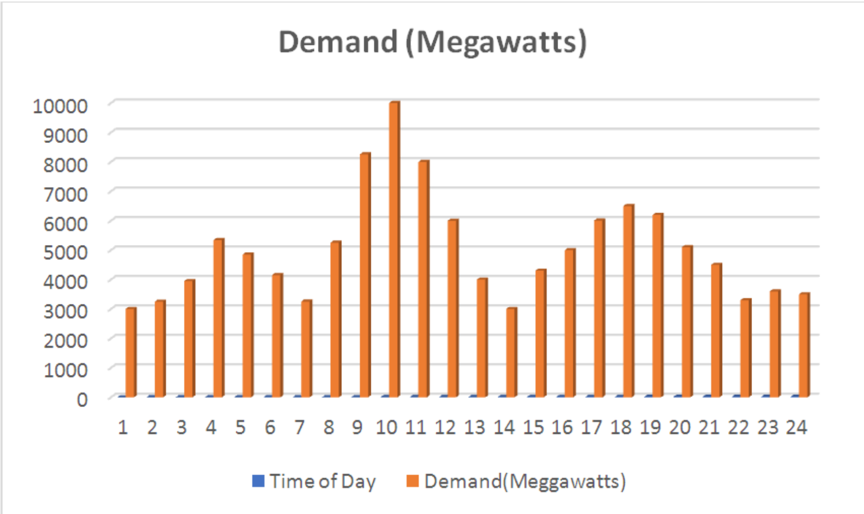

Fig. 1. Demand for electricity (megawatts) with the day hours

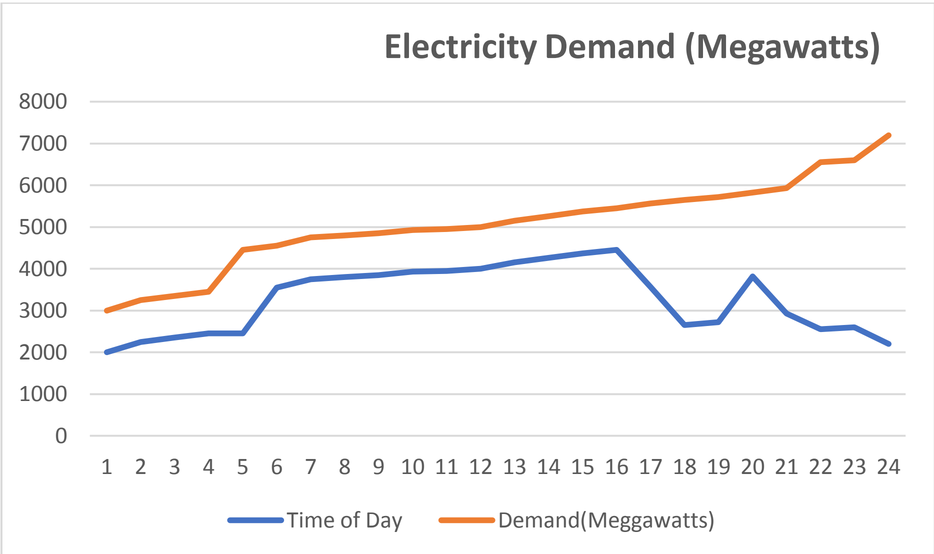

Fig. 2. Electricity demand (megawatts) over time

There is slow reconciliation of generation of electricity and integration flexibility in the energy blend regardless of its overflow in the country. Various researches have been initiated to improve electrification availability in Nigeria, starting from urban settlement down to the rural level. Recently, the Federal Government has been embarking with some organizations in the private sector to give both on-network and off-matrix sunlight-based development [5,6]. In July 2016, the permit was conceded to 14 sunlight-based designers (Quaint Abiba Power Ltd, Anjeed Innova Group, Nova Scotia Power Development Company, Pan African Solar, Nigerian Solar Capital Partner, Afrinergia Power Ltd, Motor Dusable Ltd, Nova Solar 5 Farm Ltd, Kuk Power Ltd, Middle Band Solar One Ltd, LR Aaron Power Ltd, CT Cosmos, EN Africa, Oriental Renewable Solution) and its intent to incorporate a photovoltaic system to the public matrix.

This renewable energy system development is focused on rural regions that need admittance to the lattice. It means to animate social and financial exercises by guaranteeing reasonableness through a month-to-month reimbursement plot; around 200 units were conveyed at the pilot ease in Wauna, a country town on the edges of Abuja. A full-scale provincial zap project started in 2011 and was subsidized by United States Agency for International Development (USAID) and the United States Department of energy; it had total assets of $450,000 [7]. The task gave a water siphoning framework, road lighting, a microenterprise focus, light for 20 homes, and a compact siphon for crops, as well as the capacity for medical care places, schools and strict focuses in Jigawa state [5]. The undertaking was carried out and is being kept up with by Solar Electric Light Fund (SELF), an NGO in Washington, DC. As of late, NBET marked PPAs to obtain 1,200 MW of sunlight-based power at 11.5 US pennies/kWh, expected to come online by 2018 [8].

2.1 Development of Intelligent Smart Hub Renewable Generation System

The development of an intelligent smart hub renewable generation system in Offa rural-urban centre is a method that selects the best way to sustain electrification using the analytical hierarchy process (AHP). A multicriteria tool called AHP plays a role as an examiner to figure out the best renewable energy generation system applicable in Offa. However, the study considers sunlight, wind, plant residual and water as renewable energy systems: the research project targets environment, engineering, economy, and social and geographical factor. The multicriteria decision-making tool is a more efficient model for making a decision. The research approach is based on factual data from the city. The approach eliminates the inconsistency in the generation of electricity supply [6].

This is a way to develop the Offa community and improve the livelihood of a citizen in the area. The power consumption increases monthly, and more efficient energy utilization makes the city of Offa's energy consumption fall. To integrate amount large of renewable energy into the power system in an efficient social, economical way in the rural-urban of Offa city. the study approach focuses on an intelligent hub renewable generation system. Using a smart hub is the key to achieving the transformation [1,2]. The intelligent smart hub renewable generation comprises several elements; flexible production, strong power grid and demand response [6]. The flexible output uses renewable energy from solar energy, biomass, wind power, large wind and power shell to ensure high energy generated. Hence a robust power grid is employed to transform a large amount of energy to where the energy will be consumed.

Solar energy, biomass, wind power, large wind and power shells offer solutions for providing electricity in isolated places (See [1]). In recent times, researchers have made a significant effort to solutions based on renewable energy, solely devoted to microgrids Smart Hub (SH) for developing rural and urban areas. Several microgrid systems have been installed with ratings varying from 1 kW to large volumes as a few hundred kilowatts and megawatts. Smart hub renewable energy can either be AC or DC [3]. This SH satisfies various needs, from consumer lighting and communication to commercial purposes. Seven such cases were installed in Nigeria, which cut across many states. The situation of Offa in Kwara State has been studied in depth [5,8].

Several techniques were discussed to explore locally available renewable energy resources in the Offa community. The proposed methods are carried out step-by-step in adopting smart hub renewable generation in the Offa community. This method includes an electricity generation system. The energy centre was further revised and enhanced into an intelligent smart hub renewable generation system (ISHRGS) for rural and urban centres. ISHRGS in the Offa community can be described as a system that cascading or harnesses two or more means of locally available renewable energy resources to supply a variety of energy and other needs of an urban or remote rural area in Offa centres most efficient ways; this advantage project cost-effectiveness and well structure practical implementation modality [9,10]. The study projects an ultimate goal of merging the benefits at the user end in the study area to boost the economic situation. Another method introduced recently in Offa cantered on development is "MTN LUMUS Home safe". It was earlier known as a partnership deal between MTN (a giant communication provider in Nigeria a Lumos. This was carried out to deliver affordable electricity to every home and support mini and macro businesses in Nigeria". In 2017, Lumos was launched to address the situation of the rural population with no electricity access and more to businesses ruing in urban centres in Nigeria. Lumos's technical model consists of a standardized charging station called an MTN Solar box. It is a mobile platform with up to 80 portable battery packs (PBX) and home lighting kits per station. For example, Lumos has been serving all 36 states in Nigeria, including other African countries like Ghana, Benin, Cameroon, India, Kenya, Malawi, Namibia, etc.

The development of the future energy system is based on the planning and management of the distribution network according to the Smart Grid philosophy (SG). This approach involves the extensive use of information and communication technology (ICT) and innovative control systems to enable the realization of intelligent distribution systems, active demand sharing, availability of energy storage, as well as the integration of renewable energy sources (RES) and distributed generation (DG) and the growing number of electric vehicles. The distribution industry faces the challenge of connecting and integrating renewable and other generation assets to grids that traditionally transport electricity from the transmission grids to end-users in only one direction according to a passive grid management scheme [2,9]. New power flow patterns may require changes to control strategies, improved distribution automation, enforcement of the distribution network infrastructure, and a higher level of information management and control according to the SG paradigm.

3. TELECOMMUNICATION IN POWER SYSTEM

A smart grid is an intelligent electricity network that integrates all users' actions and uses advanced information, control, and communication technologies o save energy, reduce cost, and increase reliability and transparency. Power systems remain a complex system used in communication that is categorised into four parts. The part includes power generation, power transmission, power distribution and telecommunication. The power system is incomplete without proper telecommunication infrastructure, and it is essential to every operation, such as monitoring, protection, operational control, data and voice communications [11]. That could, in essence, be if there is no communication between the protection and control devices. In a classical power system, telecommunication is more critical for reliability and continuity of operation. Looking at the intelligent hub from another edge is critical for almost every operation. The success of operation on the future intelligent smart hub renewable generation network (smart grid system) is centred on grid integrated near real-time communications between grid elements. SH occurs in all four dismissions of generation, transmission, distribution and loads, as shown in Fig. 3.

With an intelligent smart hub's structure, renewable generation starts from the centralised power generation from structural pan spot A of the generation site. It passes through transmission line B to the distribution [3,12]. The power distribution determines the level of step up and down from the distribution concerning load from the consumers' terminal. The consumer end is determined either to be active or passive. This consumer can remain passive when energy is saved for future use from some respective consumer houses—the energy is in a straight line as indicated by an arrow that points in the direction of power flow.

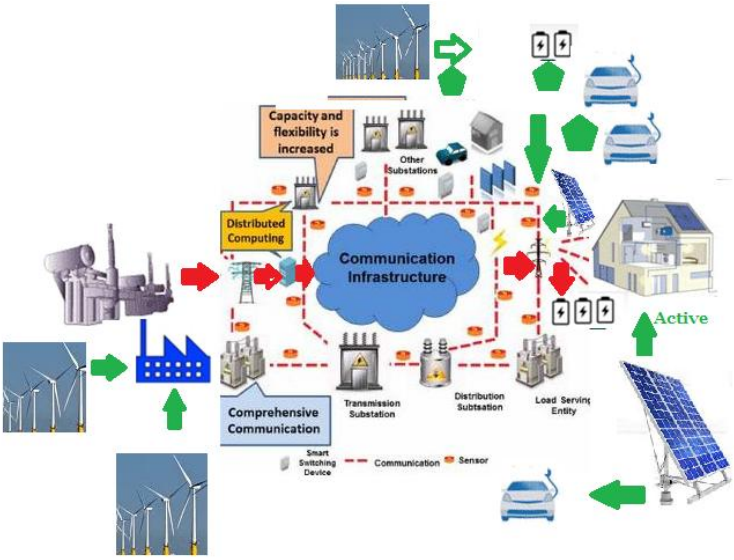

Fig. 3. Communication with the multisource generation

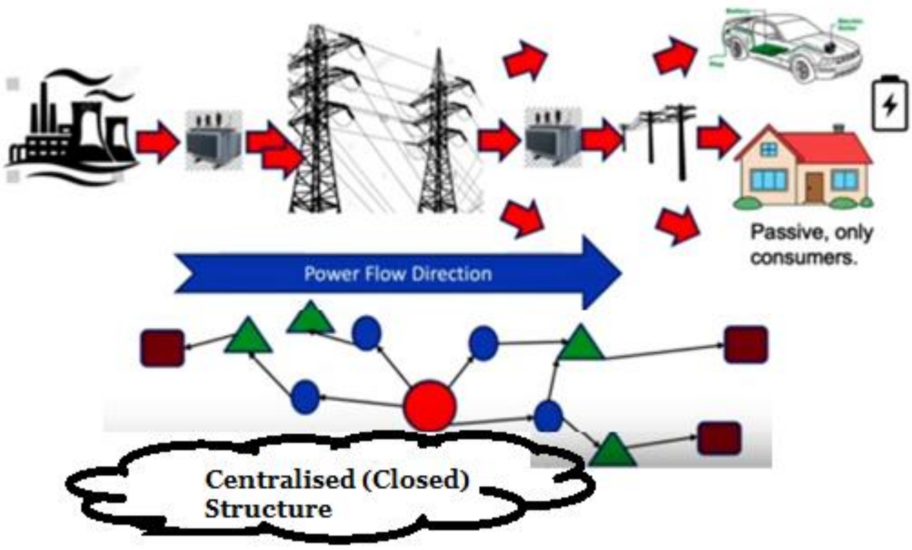

Fig. 4. The intelligent smart hub renewable schematic model

The intelligent smart hub seen in Fig. 4 shows that the intelligent smart hub generation system (ISHGS) gains the same direction as previously given in Fig. 4. Still, the need for an examined flow direction from the consumer spot is proven the opposite. Hence, the consumer remains active, and they stay in action with the presence of solar panels and wind energy which generates power [8,13]. However, when the power generated is more than what is needed in the facility, then saves power to the grid network. This implies that the direct flow of energy generation flow in the opposite (from the generation system to the grid and from the consumer terminal back to the ISHGS). When more power is negated than the demand, it's stored in the accumulator to be used later. The saved or stored power is more accessible to another consumer connected to the ISHGS.

Therefore, the power saved enables back to the grid, giving room to sell power to many consumers, preventing energy waste and increasing financial benefit. The communication from distribution to load can provide a better advantage to improve the energy system and prevent the community from a blackout in the fault account within the grid network [14]. The communication from the individual load back to the SH creates balance in the system then the use of a metering system could help the success of the ISHGS operation.

Fig. 5 above shows a metering system of SH, and the microcontroller controls the consumers' electrification system usage. Hence the smart meter is in control by a microcontroller and rounded by all intelligent systems integrated into the ISHGS. The smart meter operation control other operation like communicating with other wireless (2G,3F,4G,5D, WMAN etc.).

Interface emerged into ISHGS. Its interface to external was established for easy interoperability, enabling communication with external telecommuting media. Smart is widely used in Nigeria and other parts of the world to measure the quantity of energy from consumer terminals. The AC line indicated with RED line couple with breaker to further project power line and the GREEN line that provide DC (Solar panel, wind turbine) source from production control.

Examining the Fig. 6 of the smart hub renewable generation shows that teaches metering system provides communication with the utility and DC distribution control system, so to have a more efficient network within the community, the use of a data concentrator includes communication. It collects data from intelligent mini meters from individual consumer terminals. The Wide area network WAN connects data from the concentrator and then links up with the utility and DCS. However, 2G, 3G, 4G and 5G enable devices to be connected to the SH. In contrast, the 5G its advanced usage connects massive communication devices with the internet of a thing structuring to save many communication points. Its future development directly communicates the smart metering system to the SH. Using 2G and 3D enables communication by reducing the number of smart meters.

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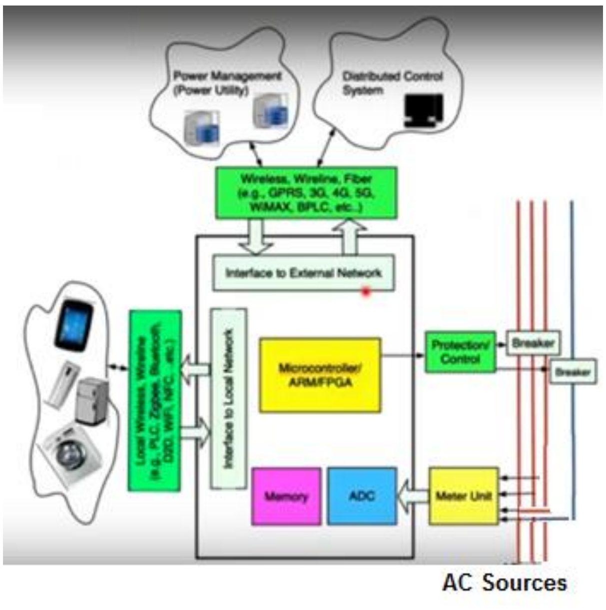

Fig. 5. Metering system of SH, and the microcontroller controls

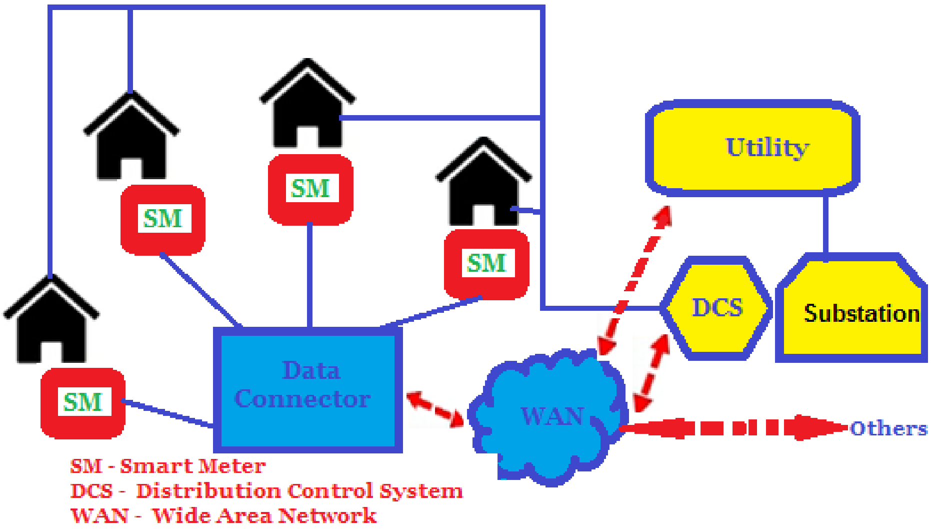

Fig. 6. Communication with the utility and DC distribution control system using metering system

Table 1. Network and no-network solutions in Offa rural and urban distribution planning

Challenge	Current solution	Future alternatives
Voltage rise	Reinforcement Operational pf. 0.95 lag. Generation tripping	Volt/VAR control Storage Generation curtailment On-line reconfiguration
Voltage drop	Reinforcement Fixed capacitor banks	Volt/VAR control Storage Demand side response On-line reconfiguration
Network capacity	Reinforcement	Storage Generation curtailment Demand side response On-line reconfiguration

The development of an intelligent smart hub renewable generation system for both urban and rural settings in the off centre will be based on planning and management of the distribution system following the Smart hub (SH) [15,16,17]. This technique involves the extensive use of Information and Communication Technology (ICT) resources and the adoption of innovative control systems. To enable the realization of renewable generation system in the study area, the active participation of demand mentioned in the context of this study, the consideration of energy storage, too much more to the integration of renewable generation system and coupled with the growing number of electricity demand for industrial usage and commercial purposes.

The economic activities of people living in the domain of Offa City as a position in the mid-Kwara State, Nigeria, are inspiring and potentially designed for the future.

Hence, the intelligent smart hub Renewable generation system for both rural-urban centres in the Offa in a wide range visible in real-time. Though existing enormous research study exists on a scale reference on the alternative power supply which proven to be environmentally friendly power projects truly exist as large hydropower dams. Until now, no genuine business massive scope project has been effectively executed other than hydropower [18,19,20]. Numerous Federal and State Government Ministries, Departments, and Agencies (MDAs), as well as confidential area players, have coordinated projects to help carry out different sustainable power innovation projects.

Some of the goals for renewable energy sources at the national level are achieving 15% and 20% commitment of hydro to the country's power. It is blended between 2015 and 2020 individually, gaining a 1% commitment of wind and sun oriented separately to the power age blend by 2022, guaranteeing substitution of half of the kindling consumed with biomass energy innovation by 2020 and use of biomass assets to get power age limit of 1000MW [21,22].

Table 2 shows the historic development of an renewable generation system in the region of Kwara State include Offa community (Rural and Urban centres) and of the selected peer districts in Offa. It is observed that Essa District performed worst of the five LGA in Kwara State in terms of absolute electricity generation system. Over a 10 year period, there was an increase of 73% in mainline generating capacity in Kwara State and neibourhood communities in Offa. By contrast, Balogun District, Ojomu North-West, Ojomu South-East district in Offa ramped up its electricity production by 322% and Shawo East, Ojomu South-East even by 421%. As a result, Ojomu North-West generated almost twice as much electrical energy in from 2002 to 2022 as Offa only has control Station in shown in Fig. 5 [26,27].

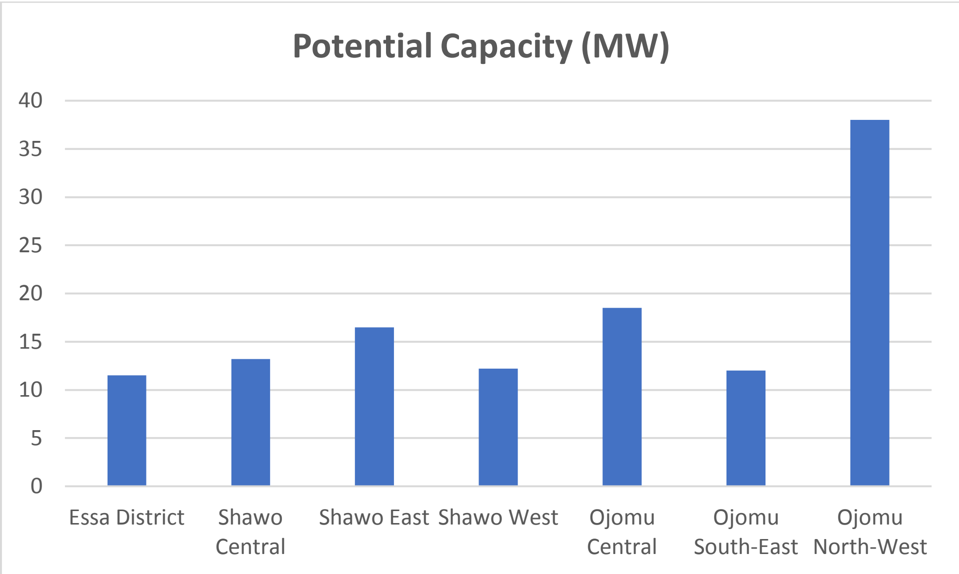

Fig. 7. Potential Capacity (MW) in the District of Offa centres

Table 2. Comparative Energy Consumption of Some Selected District in Offa Centres

Offa District	Potential Capacity (MW)	Generation Capacity (MW)	Energy Consumption (Million kWh)	Energy Consumption per Capita (kWh)
Balogun District	15.8	5	383	123
Essa District	18.1	7	183	122
Essa District	12	7.6	104	140
Shawo Central	13	4.4	134	363
Shawo East	17	11	123	439
Shawo West	12	4.9	179	344
Ojomu Central	19	2.7	29	162
Ojomu South-East	12	4.1	56	109
Ojomu North-West	38	22.3	750	505

4. RESULTS AND DISCUSSION

Having realized that Offa Community in the part of Kwara State has potential for development of an intelligent renewable energy resources, Smart Hub Energy Generation Master Plan (SHEGMP) assessment gives the opportunities in each of the required and available resource in the study area and energy value that can be obtained from each, as shown in Table 3.

According to Tables 1 and Table 2 shows the renewable generation potentials and the projected electricity supply by fuel type based on 13% economic growth rate in the selected region. The data were corresponded with once accessed from the assessment carried out by the Energy Commission of Nigeria, Renewable Energy Master Plan and Federal Ministry of Environment to support the Renewable Energy Action Plan by the Federal Government of Nigeria [23,24]. Extraction from the Table 1 and projected to Table 2, the assessment will assist in appropriate design and development successful operation of any intelligent smart hub renewable generation system to be emerged and integrated with the conventional energy generation.

The Smart Hub Energy Generation Master Plan (SHEGMP) principally n this study is to improve the development of an intelligent smart renewable generation system and eliminate obstacles that hinder this goal for rural -urban development. It integrates the framework, targets and timelines of specific renewable generation system which include hydropower, solar energy, wind and biomass [25,26]. The main objective of this plan for the Offa community and other close by towns is to promote national energy security, improve energy access. Hence, encourage research and development of renewable energy in the research domain. Part of the advantage does not limited to be achieved short-term (2021 -2025), medium term (2025 - 20230) and long-term (2030-2035) and the programmes include: National Biomass Energy Programme, National Solar Energy Programme, National Hydropower Programme, National Wind Energy Programme, Emerging Energy Programme and Framework Programme for Renewable Energy Promotion according to Esapour [27]. A summary of the renewable energy targets is shown in Table 4.

Table 3. Renewable Energy (RE) Potentials in Offa centres [25]

Required Resources	Target	Review
Large Hydropower	10 MW	1800 MW exploited
Small Hydropower	1,500 MW	63.1 MW exploited
Solar	1.0 kWh/m2 /day – 6.5kWh/m2 /day	2 MW dispersed solar PV installations (estimated)
Wind	3-5 m/s@10m height mainland	Electronic Wind Information System (WIS) available;10MW wind farm in Offa recommended
Biomass (non-fossil organic matter)	-Municipal waste -Fuel wood -Animal Waste -Agric Residue -Energy crops	-1.5 million tonnes produced in 2022 and now estimated at 0.5kg/capital/day 23.4 million tonnes/yr fuel wood consumption. 5 million assorted animals in 2021, -1.4 million tonnes/yr produced -28.2 Thousand hectares of arable land; 1.5% cultivated

Table 4. Summary of Renewable Energy Targets for Urban- Rural canters in Offa

S/No	Source	Short Term	Medium Term	Long Term
1	Solar Thermal	-	2	6
2	Biomass	-	122	800
3	Wind	1	25	40
4	All Renewable	2200	7405	69,445
5	All Energy Sources	18,000	40,000	195,000
6	% of Renewable	15%	25%	39%
7	Large Hydropower	1740	5540	39,000
8	Small Hydropower	110	644	15,000
9	Solar PV	5	133	650

5. CONCLUSION

The generation system can be safe from invasion by unauthorized personnel. Hence cleaner power generation is compulsory to mitigate climate pollution for long-time problem of running out of fossil fuels. The approach in the distribution of electrification concept could be more efficient through renewable resources like wind turbines and solar cells. The excess energy generated from the proposed intelligent mart hub generation system can be stored for later use when needed, and this could be achieved through energy-storage elements connected to the power grid system. The consideration of SH to Offa community centre on the feature of high adaptability to meet the temporal needs efficiently, and the features reflect the intelligent character of the smart hub concerning electricity demand in the region.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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