The Hybridization of Renewable Energy Systems in Nigeria

Amayanvbo, I., Ojo, O.K and Omorodion, I.
Department of Electrical Electronic Engineering
School of Engineering
Edo State Polytechnic.

Abstract-
As the world's energy consumption continues to rise on a regular basis, the need for additional power generation will become unavoidable. In order to meet this need for electricity, renewable energy supplies must account for a large portion of the entire demand. In the form of a hybrid system, wind turbine technology paired with solar photovoltaic (PV) technology can play an important part in reducing our future energy consumptions while providing a cost-effective energy conversion system. According to this paper, the possibility of hybridising the various renewable energy sources available in Nigeria is being investigated, as well as the sustainability, challenges, and benefits associated with hybridising the various renewable energy sources (PVs and wind turbines) that are abundantly available in the country. The hybrid energy system, which consists of a combination of numerous energy resources that are readily available in Nigeria, is an excellent answer to the country's persistently erratic power supply. As a result, the quality of life will increase, which will help to reduce atmospheric degradation.

Keywords- Renewable energy system, Photovoltaic, Wind turbine, Control system, integration schemes.

1. INTRODUCTION

People are unable to function without access to some type of energy. Energy is required to illuminate our surroundings, power our homes, schools, hospitals, workplaces, and businesses, as well as to encourage economic development and development. It is a well-known fact that the availability of electrical power is critical to a country's economic development. In contrast to the growth and stability seen by the Nigerian telecommunications business, the country's electrical market is beset by numerous issues. These issues include a delayed increase in generation capacity, interference with the market deregulation

process by the government, vandalism of electrical transmission lines and distribution equipment, inadequate maintenance of existing electrical infrastructure, and corruption in the electricity industry.

An alternative to convectional power generation in a rural location with low energy consumption is discussed in this research, which is based on a hybridised renewable energy supply system. A feature of life in Nigeria is that the country is blessed with plentiful sunshine throughout the year, and there is also a dense canopy of greenery covering the entire country. According to Maren (2013), Nigeria is blessed with an annual average daily sunshine of 6.25 hours, ranging between 3.5 hours at the coastal region and 9.0 hours in the northern region, which receives approximately 5.08 x 1012 kWh of energy per day from the sun, and if solar energy appliances with only 5 percent efficiency are used to cover only 1 percent of the country's surface area, then 269.24 MWh of electricity can be generated annually. This quantity of electrical energy from the sun is equal to 4.66 million barrels of oil each day, which is a significant amount of oil. This opens up opportunities for Nigeria to have more access to and availability of solar energy, allowing the country to advance its solar energy technology [11].

When it comes to wind energy generation, there is an abundance of potential. Depending on the wind speed, this potential is available in Nigeria at yearly average speeds of around 2.0 m2 in the coastal region and 4.0 m2 in the northern portion of the country, with an average annual wind speed of not less than 5 m/s at a height of 10 m above ground level [10, 11]. This includes assessing the feasibility of combining the various renewable energy sources available in Nigeria and determining whether such a combination will be sustainable in the country's remote rural areas.

1.2 The Endowment of Nigeria's Energy Resources

Nigeria has been endowed with an abundance of energy resources. Both renewable and nonrenewable energy resources are available in a plethora of configurations. For example, Nigeria is Africa's leading producer of fossil fuels and is home to the world's seventh largest natural gas resource [Barber, 2014]. The Nigerian oil and gas industry, according to Iwayemi (2008), has an estimated reserve of 35 billion barrels of oil, 185 trillion cubic feet of natural gas, and 2.75 billion metric tonnes of coal, among other resources. As a result of these abundant renewable energy resources, particularly in the Western region,

Nigeria, particularly the country's solar radiation but also biomass, wind, and a significant body of surface water that could be used for small hydroelectric power generation, the country is poised to become a global leader in small hydroelectric power generation. According to estimates by Iwayemi (2008), Nigeria possesses 14,750 MW of hydropower, 3.5-7.0 KW/m2 per day of solar radiation, 2.0-4.0 m/s wind energy with a capacity of 150,000 TJ/yr, and biomass with a capacity of 144 million tonnes per year. According to Simonyan and Fasina (2013), the Nigerian biomass resources from residues and trash were 47.97 million tonnes of organic energy (MTOE). Nigerians are suffering from an epileptic electricity supply, despite the fact that the country has tremendous energy resources. What actions should be taken in order to remedy the situation? A municipal-based integrated electrical energy system powered by a combination of renewable energy sources is proposed as a viable solution to the energy supply problem. Some of the questions that should be explored are whether or not it will be workable and whether or not it will be sustainable.

2. Hybridization of wind and solar energy systems for rural areas is being investigated.

After extensive research by renewable energy experts, a hybridization of electric systems that incorporates both wind energy and solar PV technology will be found to have a number of advantages over a single system. During the summer months in the United States of America, when the sun shines the brightest and longest, the wind speed is at its lowest. Furthermore, the wind is particularly strong during the winter, when there is less sunshine accessible. As a result, the peak operating times for wind and solar energy occur at different times of the day throughout the year [3], depending on the season. Hybrid power systems create electricity only when it is required, making the integration of wind and solar energy more attractive. They have also been used to replace oil-based energy sources [4].

In contrast to conventional electrical systems, hybrid electrical systems are self-contained and function "off-grid," that is, they are not connected to a power distribution system. When a wind or solar energy system generates electricity, it can be supplemented by batteries or an engine generator that runs on

conventional fuels such as diesel, gas, or petrol to produce power. When the batteries become depleted, the engine generator can be used to supply power and recharge the batteries as needed. It is critical that the storage capacity be large enough to meet the electrical load demand during periods when the battery is not being charged. Battery banks should have sufficient capacity to supply the electric load to the community on a continuous basis [7].

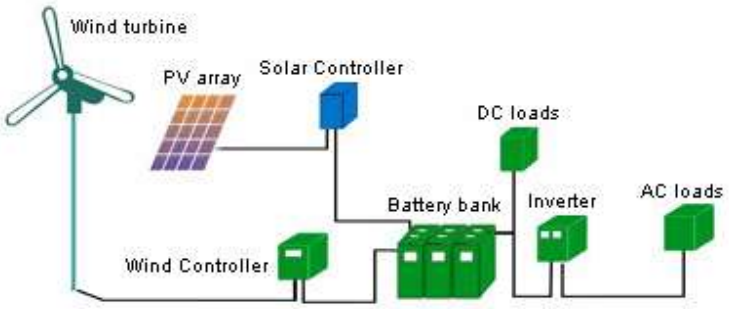


Fig. 1: Hybridization of Wind & Solar PV Systems

ENERGY PROFILE

Nigeria

IRENA
International Renewable Energy Agency

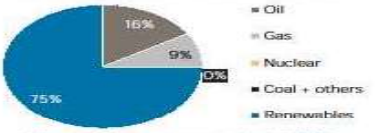
SUSTAINABLE DEVELOPMENT GOAL 7: ENERGY INDICATORS (2017)

Renewable energy (% of TFEC)	82.6	Access to electricity (% of population)	54.4
Energy efficiency (MJ per $1 of GDP)	6.4	Access to clean cooking (% of population)	8
Public flows renewables (2017 USD M)	5075.7	Per capita renewable capacity (W/person)	11.2

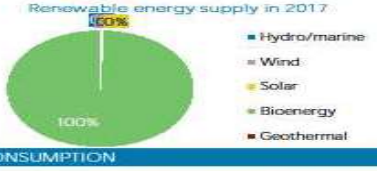
TOTAL PRIMARY ENERGY SUPPLY (TPES)

TPES	2012	2017
Non-renewable (TJ)	1 337 808	1 652 190
Renewable (TJ)	4 543 348	4 920 398
Total (TJ)	5 881 156	6 572 588
Renewable share (%)	77	75
Growth in TPES	**2012-17**	**2016-17**
Non-renewable (%)	+23.5	+12.2
Renewable (%)	+8.3	+2.4
Total (%)	+11.8	+4.7
Primary energy trade	**2012**	**2017**
Imports (TJ)	660 871	979 754
Exports (TJ)	5 931 662	4 756 625
Net trade (TJ)	5 270 791	3 776 871
Imports (% of supply)	11	15
Exports (% of production)	53	46
Energy self-sufficiency (%)	189	158
Net trade (USD million)	+ 119 454	+ 33 961
Net trade (% of GDP)	+26.0	+9.0

Total primary energy supply in 2017



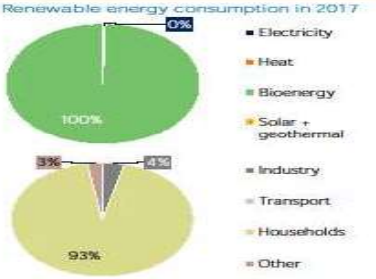
Renewable energy supply in 2017



RENEWABLE ENERGY CONSUMPTION

Consumption by source	2012	2017
Electricity (TJ)	18 117	20 152
Heat (TJ)	0	0
Bioenergy (TJ)	4 145 952	4 508 037
Solar + geothermal (TJ)	0	0
Total (TJ)	**4 164 069**	**4 528 189**
Electricity share (%)	0	0
Consumption growth	**2012-17**	**2016-17**
Renewable electricity (%)	+11.2	-13.4
Other renewables (%)	+8.7	+2.5
Total (%)	**+8.7**	**+2.4**
Consumption by sector	**2012**	**2017**
Industry (TJ)	312 168	176 180
Transport (TJ)	0	0
Households (TJ)	3 722 808	4 232 747
Other (TJ)	129 093	119 263
Renewable share of TFEC		82.6

Renewable energy consumption in 2017



In a rural area, off-grid or stand-alone renewable hybrid energy systems are recommended.

In some cases, according to the United States Department of Energy, off-grid or stand-alone electrical systems are more cost-effective than connecting to the power grid in rural areas of the country. Figure 2 depicts a rural area with low energy usage that will profit from and enjoy the hybridization of wind and solar energy. Stand-alone renewable energy systems, which are not connected to the power grid and are used by domestic loads users or small businesses, make economic sense and are in line with their environmental ideals when compared to other options. To create and distribute reliable electricity, cut costs, and minimise annoyance, successful stand-alone systems employ a combination of approaches and technologies to achieve success. The use of fossil fuel or renewable hybrid systems, as well as lowering the quantity of energy necessary to meet load demand, are some of these solutions that can be implemented. In addition to the purchase of solar panels or wind turbines, it is necessary to make an investment in other equipment known as balance-of-system equipment in order to properly transport electricity to the consumers.

This equipment includes:

- Batteries
- Charge controller
- Power conditioning equipment
- Safety equipment
- Meters and instrumentation

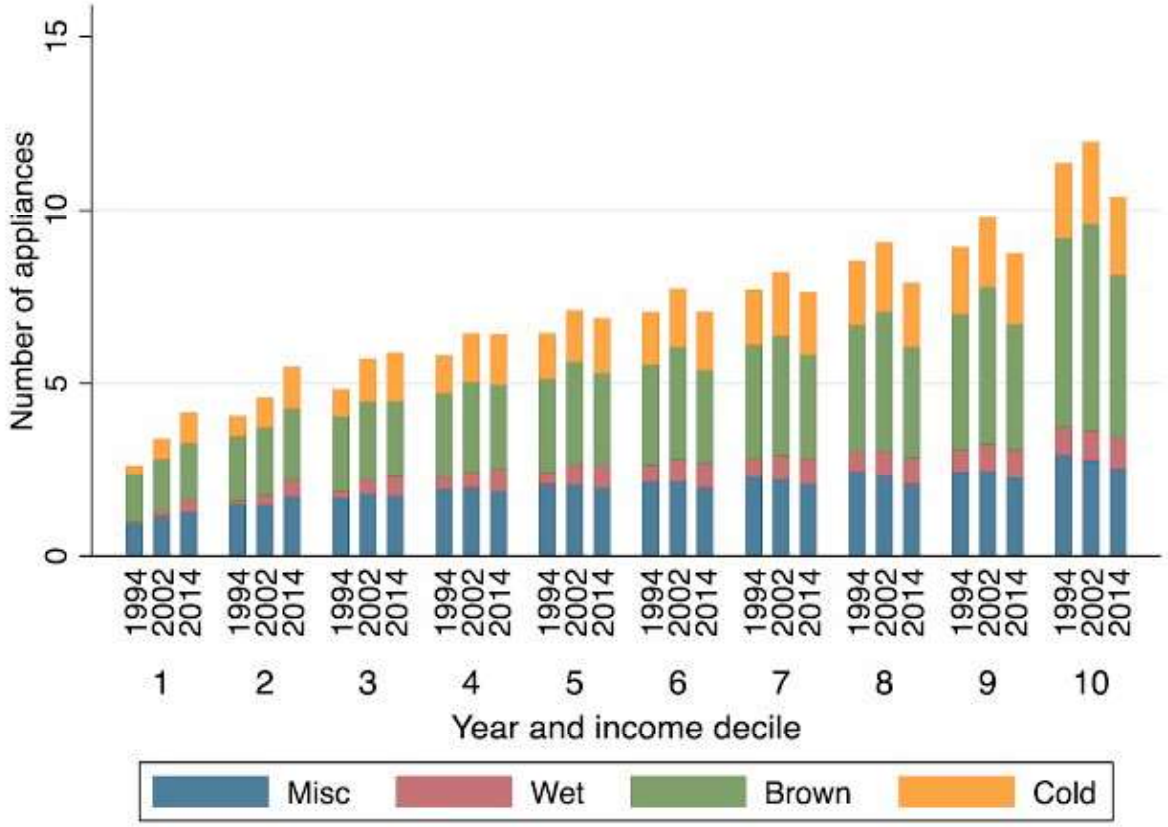


Fig 2: Typical load consumption of a rural area

3. Sustainability of Hybrid Energy Systems in rural area.

In order to achieve sustainability, it is necessary to strike a balance between human endeavours such as cost, health, and comfort, as well as environmental issues (such as resource consumption and ecological deterioration) [8].

So far, so good. There is no official sustainability analysis of the few hybrid energy systems that exist in Nigeria, which is a positive thing. Some hybrid energy developers in Nigeria have reported that the system has assisted them in lowering their energy costs, improving the stability of their services, and lowering their carbon footprints [5]. The examination of sustainability, on the other hand, extends beyond the qualities of a system's perceived advantages. There have been several projects aiming at resource conservation, such as recycling of waste materials, that have ended up having more detrimental consequences on the environment than they had anticipated, according to Barber (2014). This is in direct opposition to the intended purpose of the initiative. The total

consequences would not be obvious or noticeable unless the system was subjected to a thorough investigation. It is therefore necessary to conduct a comprehensive and quantitative examination of the hybrid electrical system in such a way that stakeholders may gain a clear picture of the extent to which the system is sustainable [1].

In Nigeria, there are several challenges associated with implementing hybrid energy systems.
The few cases of hybrid energy supply projects that have been implemented in Nigeria have demonstrated tremendous potential as a solution pathway for resolving the country's energy supply systems [10]. It is probable that it will be impossible to identify all of the problems that could arise during the development and operation of all types of hybrid energy systems in the future. In any case, there are some challenges of sustainability that must be considered regardless of whether or not a hybrid system is used. The following are some of the primary problems associated with hybridising energy systems in Nigeria's rural areas:
• Integrating the system in such a way that a sufficient amount of energy is available on a continuous basis, with or without interruption, is essential.
• Ensuring that the system's design is simple enough that it can be maintained and even upgraded by the experts and craftsmen who are readily available in the area.
• Technically, depending on where you are, a wind energy system may not be viable due to the low wind speed that is experienced there.

Hybrid energy systems have a number of advantages, which are detailed in section 3.2.
It ensures a consistent source of energy throughout the day and night. When one of these items is not available in sufficient amount, the other is available to supplement it when one is not.
It is not necessary to depend on external energy supplies for energy generation in a hybrid system because the system is predicated on ample local resources. This eliminates the problem of relying on external energy supplies for energy generation that could be disrupted by vandalism.

In isolated areas or terrains where grid connections are impossible or prohibitively expensive, it can be used to supplement power.

• It necessitates the participation of people of the local communities in the provision of necessary services for its operation, hence increasing economic opportunities.

• It increases employment in the local area, which in turn has the effect of reducing rural-to-urban migration rates.

• A steady supply of hybrid electric energy would reduce the need for expensive and polluting fossil fuel-powered generators by lowering corporate operating costs, reducing idle time, and increasing productivity, among other benefits.

• It helps to reduce pollution, which can lead to health concerns, while also raising the overall standard of living.

• It makes it possible for locally created products to compete on the market.

• It encourages the growth of small and medium-sized businesses.

• It creates employment possibilities, decreases social vices, promotes peace and economic stability, and all of these things are good.

4. Concluding remarks

It has become clear from this discussion that the development of hybrid energy systems in rural areas is still in its early stages. Hybrid energy systems based on a combination of numerous energy resources that are readily available in Nigeria appear to be a promising solution to the country's persistently erratic power supply. Because it will increase the overall quality of life while also reducing environmental damage.

It will also restrict migration to urban areas, hence reducing overpopulation in those areas. To get it right the first time, a delicate balance between human and environmental considerations would be required. It has been determined that the proposed or current hybrid energy system will be sustainable according to a balanced criterion developed in this study. The following step would consist of case studies that would make use of the set of recommended criteria in order to assess the long-term viability of a number of hybrid energy systems in Nigeria. Investors, regulators, researchers, and developers in hybrid energy systems might find it beneficial in making decisions about which hybrid energy systems options (wind, solar, biomass, etc.) to consider when making a decision about which hybrid energy systems option to consider.

References

[1] Barber D A 2014 Nigeria Moving into Solar Energy to Spur Business Growth, https://moguldom.com.

[2] Dunmade I 2016 Hybridizing Renewable Energy Systems in Nigeria: A Contextual Framework for Their Sustainability Assessment. European J. Engineering and Technology. Vol 4. No.5. ISSN 2056-5860

[3] Lal D K, Dash B B and Akella A K 2011 Optimization of PV/Wind/Micro-Hydro/Diesel Hybrid Power System in HOMER for the Study Area. International J. Electrical Engineering and informatics. Vol 3, No 3

[4] Nema P, Nema R K and Rangnekar S 2009 A current future state of art development of hybrid energy system using wind and PV-solar. Renewable and sustainable Energy Review.

[5] Okere R 2015 BPE clarifies status of N213bn capital injection to power firms

[6] Olatomiwa L, Mekhilef S, Huda A S N and Ohunakin 2015 Economic Evaluation of hybrid energy system for rural electrification in six geo-political zones in Nigeria.J Renewable Energy, Vol 83, pp 435-446.

[7] Simonyan K and Fasina O 2013 Biomass resources and bioenergy potentials in Nigeria. African J. Agricultural Research, vol 8, No 40.

[8] Stanford University 2005 Guidelines for Lifecycle Cost Analysis – Land and buildings

[9] US Department of Energy at http://energy.gov/energysaver/

[10] Vincent, E. N. and Yusuf, S.D. (2014) Integrating Renewable Energy and Smart Grid Technology into the Nigerian Electricity Grid System. Smart Grid and Renewable Energy 5, 220-238.

[11] Maren, I. Borok, Agontu, J. Agandu, Mangai. M. Morgan, (2013). Energy Security in Nigeria: Challenges and Way Forward. International J. Engineering Science Invention, Vol 2 Issue 11, PP.01-06

[12] Federal Ministry Of Power, Works And Housing 2015, Rural Electrification Agency (REA) Final Draft Rural Electrification Strategy & Plan for Implementation.

[13] Srivastava S D and Banerjee R 2015 Hybrid Renewable Energy Systems & their Suitability in Rural Regions. Journal of Mechanical and Civil Engineering. Vol 12, PP 117- 120.