MOBILE HYBRID WIND/SOLAR/MAINS (RENEWABLE) ENERGY SYSTEMS FOR USE IN CROSS RIVER UNIVERSITY OF TECHNOLOGY: BEYOND GREEN SKY THINKING

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ABSTRACT

We exploit the twin challenges of energy infrastructure deficit and unsustainable electricity power supply for academic activities in the Cross River University of Technology, Calabar to study, design, and build a mobile hybrid Solar and Wind renewable energy system with insights from the discipline of Development economics. Arguably, the debate around emission-first and adaptation approach compels a hybrid renewable system that harnesses both solar, wind and mains energies, thereby transition to sustainable energy production and use. Drawing therefore from an experimental evidence of the prototype and use of the system by staff and students of the University, three main arguments are presented: first, we argue that substantial evidence sufficiently linked fossil fuel and greenhouse gas emission; and hence their consequences on population and ecology; second, we contend that a nuanced adaptation of renewable energy technologies would contribute to shifting away from fossil fuel energy regime dependence to green energy technologies in the Cross River University of Technology, Calabar in particular, and Nigeria in general; Third and no less important, we argue that the project contributes to the urgent need to grow and re-balance Nigeria's oil-centric economy. Following recommendations from this project, de-optimizing fossil fuel energy is a *sine qua non*, and the conclusion developed in this paper would enhance and sustain the direction of increased policy support and physical infrastructure for renewable energy research, development and use, and thereby provide a sustainable and off-grid solution to domestic and official deficits in electricity power supply in the university community and beyond.

Keywords: Green Energy Technologies, Economic growth and development, Infrastructure deficit, Renewable energy hybrid system.

1.0 INTRODUCTION

Arguably, Nigeria is an oil-centric economy, but the country's energy infrastructure is deficit and electricity power supply is endemic for its estimated 200 million people. One of the most daunting challenges facing academic activities in Cross River University of Technology, Calabar is the lack of steady power supply. There is hardly electricity available on the national grid and the university depends on diesel generators to provide only a fraction of its energy requirements. While the university continues to pay huge sums to the *Port Harcourt Electricity Distribution Company* (PHEDC) for electricity that hardly comes, the university's central diesel generator is inadequate to provide enough power for any of its campuses. Offices are dark and stuffy, and most staff cannot work with their computers and under this condition. These inadequacies arise from national grid deficit lack internal generator mount. Among the workforce, much work hours is generally lost to the absent of electricity. Even when staff take official work home, the absentee national grid makes working at home difficult without expensive fuelling of domestic electricity generators to perform official duties.

The geographical location of the headquarters of the university reveals that it lies close to the Calabar Creeks, with the coordinates 4.9308° *N* and 8.3303° E, which has much sunshine throughout the year and the average wind speed is about 3km/h, bringing viability to the use of renewable energies within the vicinity (National Geographic, 2019). This study seeks to design and build prototype 500w and lOOOw mobile hybrid wind/solar/mains renewable energy systems that can be used by staff of Cross River University of Technology to perform their duties both at the work place and at home.

The Cross River University of Technology, Calabar (CRUTECH) was established in 2002 by the government of Cross River State, Nigeria. The University is an amalgam of four campuses, namely: Calabar, Obubra, Ogoja and Okuku; and has ten faculties - Agriculture and Forestry, Architecture, Biological Sciences, Communication Technology, Education, Engineering, Environmental Sciences, Health Sciences, Management Sciences and Physical Sciences. As with all institutions in Nigeria, one of the most daunting challenges facing academic activities in CRUTECH is power. Even this inadequate diesel power generation comes at a huge cost. According to Assurance Power Systems (2019), it costs about $122 (about &44,000) a day to run a 20-kilowatt diesel generator. Thus, the cost of running the SOOkva diesel generator at the Calabar Campus per hour is definitely abortive, which is why electricity is scarce on campus, leading to severe losses in academic inputs and outputs.

In the near-absence of power from the national grid, the electricity provision in CRUTECH-wide campuses is based on fossil fuels regime, which remains a challenge to the University administrators both in terms of environment related issues, as well as the economy of production and use. Though oil and gas are Nigeria's strategic minerals, and fossil fuel in general supplies 80 per cent of the world's energy needs, it is finite and has provoked growing concerns about climate change and health (Loh et al, 2007; Ravishankara, Daniel and Portmann, 2009; Olsson et al, 2011; Takon, 2014). While diesel is the most commonly used fossil fuel for large-scale electricity generators, its exhaust is classified by the *International Agency for Research on Cancer as* probably carcinogenic to humans (Olsen et al, 2011). Against the rising global environmental concerns about fossil fuel use, research institutions like CRUTECH should either be sourcing electricity supply from Nigeria's national electricity grid, or deploying sustainable renewable solutions. Nevertheless, the University generates its own electrical power permanently because of energy infrastructure deficit in Nigeria. For example, electricity supply from the national grid runs at about 15% a month and for half of a calendar year. In this context, beside the standby generator's annual servicing and consumption charges - constituting a prohibitive percentage of CRUTECH's annual budget -, more importantly, diesel powered generators have cumulative health consequences on campus populations and ecology.

Against the backdrop of incapacitated national electricity grid, the prohibitive cost and hazardous nature of using fossil fuel to generate electricity, the demand for power continues to rise in Nigeria (Ibitoye 2007). Within Cross River University of Technology, more faculties and departments have been recently created, leading to the upsurge in student intakes. This sudden increase in the campus population further worsens the power crises and places urgency in the search for alternative sources. This is where renewable energy sources become most important. Since the power generated from these two renewable sources are independent of the national grid and diesel generators, there are huge benefits in taking the renewable energy course of action. As Chineke, Nwafor and Okoro (2007) indicates, there are benefits of utilizing renewable energy sources in Nigeria (Takon, 2018). It is therefore important to harness and use the prevailing renewable energy sources within the environment to generate much needed electricity for use in Cross River

University of Technology in particular, and Nigeria in general. In this sense, the challenge is to provide energy that populations within the campuses can use efficiently, sustainably and without contributing to the pollution of the environment. Indeed, across the world, governments, individuals, and businesses – profit and non-profit alike, are rapidly embracing sustainable energy mix.

2.0 LITERATURE REVIEW

Beside the expenses of acquiring and maintaining diesel and other fossil fuel electricity generators, the overriding factor that make them unsuitable for contemporary use is the dire effect on the environment (Takon, 2014, 2018). Several studies have been conducted on the pollution from diesel, for example. However, unlike most epidemiologic studies evaluated as limited because they lack adequate control for potential confounders, Olsen et al, (2011) reported exposure-response relationships in their investigation of lung cancer risk associated with occupational exposure to diesel motor exhaust, while controlling for potential confounders. Their study pooled information on lifetime work histories and tobacco smoking from 13,304 cases and 16,282 controls from 11 case-control studies conducted in Europe and Canada. Consequently, the researchers applied a general population job exposure matrix based on ISCO-68 occupational codes, assigning no, low, or high exposure to diesel motor exhaust. The study was able to associate cumulative diesel exposure with an increased lung cancer risk highest quartile versus unexposed (odds ratio 1.31; 95% confidence interval, 1.19-1.43). There was also a significant exposure-response relationship (P value < 0.01). The researchers found corresponding effect estimates were similar in workers never employed in occupations with established lung cancer risk, and in women and never-smokers. Results showed a consistent association between occupational exposure to diesel motor exhaust and increased risk of lung cancer. The authors note that the resulting association is unlikely explained by bias or confounding, which they addressed by adjusted models and subgroup analyses. With the volume of research underscoring the negativity of using fossil fuel, global attention is increasingly turning to renewable sources such as solar and wind energies (Glunt, 2002; and Roberts, 2004).

According to *National Geographic* (2019), solar energy is the technology used to harness and make the sun's energy useable. Made of semiconductor materials, the cells are like those found in computer chips. As sunlight hits the cells, electrons are knocked loose from their atoms. Electrons then generate electricity as they flow through the cell. In a solar system, the photovoltaic panels generate power that supplies gadgets directly and also feeds into battery until it is full, for night time energy demands (Hockenos 2019). As of 2011, the technology produced less than one tenth of one percent of global energy demand. However, solar energy use has surged at about 20 percent a year over the past 15 years because of rapidly falling prices and gains in panels' efficiency. Solar energy is lauded as an inexhaustible fuel source that is pollution-and often noise-free (National Geographic, 2019). The growing popularity of solar panel and battery systems is driven by a drop in lithium-ion battery prices (Hockenos, 2019). As Gearinoe (2019) notes, prevailing market forces are helping the world move away from fossil fuels, and coal-fired power plants, for instance will not be able to compete on price with new wind and solar power by 2025.

Instructively, *The NEED Project* (2018) solar energy can be used to produce electricity by using photovoltaics (PV) and solar thermal systems. Photovoltaic comes from the words "photo", meaning light, and "volt", which is a measurement of electricity. Solar cells are made up of silicon and can supply energy to anything that is powered by electricity. Electricity is produced when radiant energy from the sun strikes the solar cell, causing the electrons to move around, which starts an electric current (see Fig. 1, p.5). This process takes place silently and instantly, without mechanical parts that will wear out. Opened in 2015, generating 550 megawatts of electricity to power 150,000 homes, the Desert Sunlight solar project in California is one of the largest photovoltaic plants in the world *(The NEED Project*, 2018).

On the other hand, solar thermal systems, also called concentrated solar power (CSP), use solar energy to produce electricity in a different way. They use mirrored surfaces of solar collectors to focus sunlight onto a receiver that heats a liquid. Steam is produced from the heated liquid,

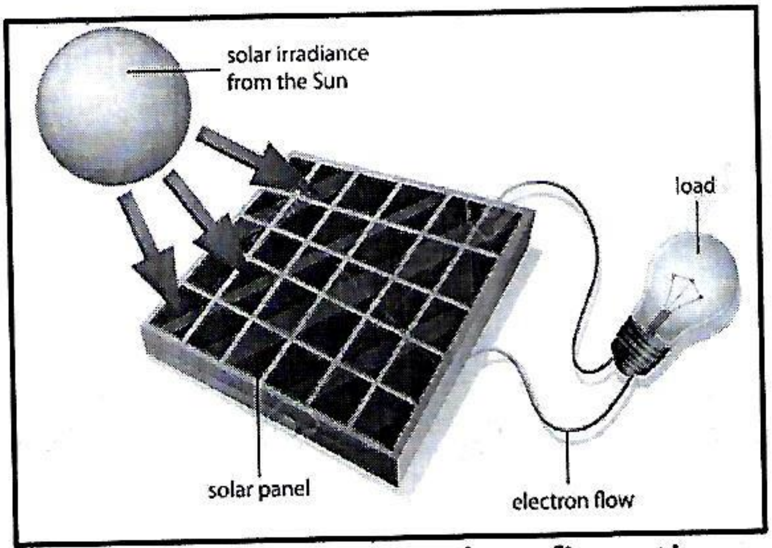

Fig. 1: Solar energy and configuration system.

and used to power turbines and generate electricity in the same way that coal plants do. Solar energy has great potential because it is free, its supplies are unlimited, it does not pollute the environment and cannot be controlled by any one nation or industry. By improving the technology to harness the sun's enormous power, mankind may never face energy shortages again (Wasfi, 2011; and *The NEED Project,* 2018). Photovoltaic complete system usually consists of photovoltaic units, batteries, charging controllers, inverters, load controllers, circuit breakers and wiring (Wasfi, 2011).

While solar systems use photovoltaic cells, wind systems use wind turbine generators to harness windspeeds, and then convert it to electrical energy (Fig. 2). The technology of wind energy conversion is not a new one because it has been in use for mechanical applications like grain crushing since 644 A.D. in areas like Persia, Afghanistan (Hau, 2000). Vertical axis turbines were the first wind mills and they used sails around a pivot to generate mechanical power. The classical or horizontal axis wind turbine is independently attributed to European designers since 1180 (Kirsch, 2009).

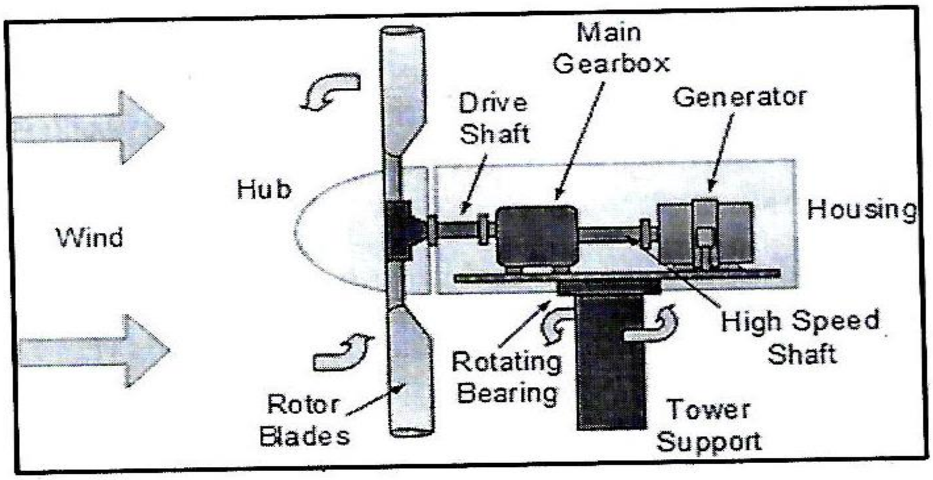

Fig. 2: Wind turbine generator system.

The windmill technology reached its peak in Europe in the Early 19th century, and spread to the British and Dutch inhabited East coast of the United States of America (Kirsch, 2009), it was Dane Poul La Cour that built the first purely electricity generating wind mill in Denmark, which drove a dynamo in 1891. By 1918, there were about 120 electricity generating wind turbines operating around Europe (Kirsch, 2009). From that time, wind has continually being harnessed for generating electricity. In fact, Boyle (2007) states that wind power generation will end up being a sustainable and economically viable energy alternative in the world of the future. The procedure for the design and installation of a wind energy system includes determining the application, the load, estimating costs and the availability of the renewable resources at the location where the system is to be installed (McGowan, 2003; Alkhalidi and Husein, 2018). The key considerations for designing and installing a wind energy system, includes the type of wind turbine, as can be seen in Figs. 3 and 4 (Heier, 1998; Gipe, 2004; and Pond, 2012).

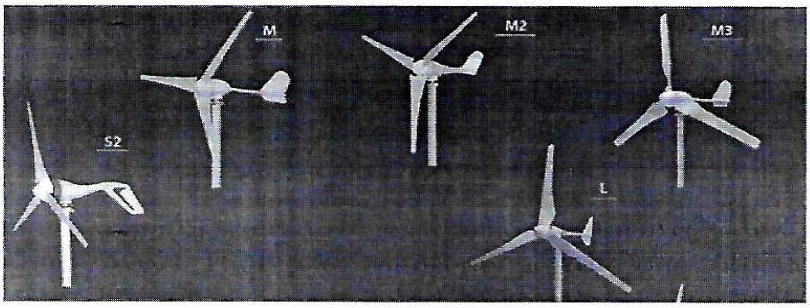

Figure 3: Horizontal Axis Wind Turbines

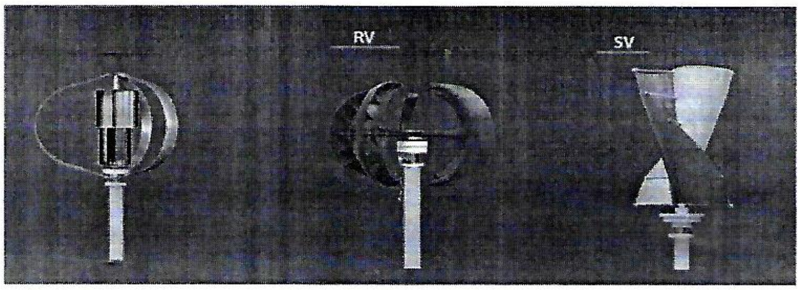

Figure 4: Vertical Axis Wind Turbine

There are two basic architectures of wind turbines, the horizontal axis wind turbines (HAWT) and vertical axis wind turbine (VAWT). Both take wind energy from one direction, as wind flows over the blades and creates lift, which is transformed into rotational energy. Most HAWT are capable of rotating at much faster speeds than the wind is travelling. On the other hand, the VAWT is less popular but more effective at lower start up wind speeds of 1.2m/s. VAWTs use wind from all directions without the need to change the angle of incidence (Pond, 2012). For this study, a vertical axis wind turbine (VAWT) shall be used because it will maximise the prevailing wind in the university premises in particular, and Calabar in general.

For a hybrid system as this study seeks to produce, it is a combination of solar and wind systems, with the effect that electricity shall be generated in the day time with solar and wind, and at nights with wind. Thus, in addition to the solar panels and wind turbine generator needed for a wind/solar hybrid renewable energy system, the following components are also required:

i. De-Ac inverter

The power inverter transforms direct current (DC) generated from the wind turbine generator into alternating current (AC) and channels it to charge the battery bank. It also changes the DC output stored in the battery bank to an AC current for normal use of AC-functioning electric appliances (Pond, 2012; and Alkhalidi and Husein, 2018), such as studio lights.

ii. Hybrid Charge Controller

This controls the voltage and current originating from the wind turbine generator into the storage and usage system. The charge controller decides how much current is injected into the batteries and adjusts charging rates according to the battery's charge level to allow charging closer to the battery's maximum capacity in order to sustain the battery bank life span (Alkhalidi and Husein, 2018). Since it is a hybrid system that was designed, it required a wind/solar hybrid charge controller (Fig. *5).*

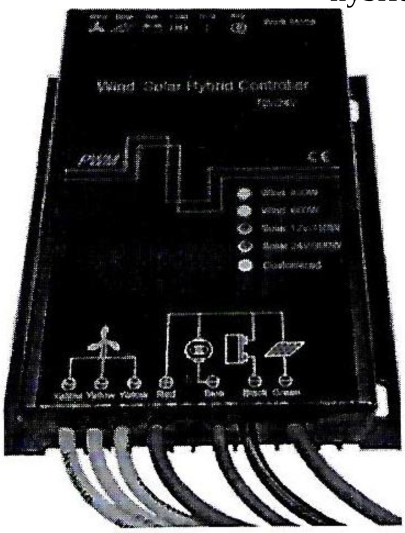

Fig. 5: A wind/solar hybrid charge controller.
Note that the left "input" wiring is for wind, while the right is solar.

iii. Battery Bank

This is an arrangement of batteries that store electric energy generated from renewable sources like wind generators and solar panels. Normally a battery bank consists of a number of batteries which are wired in series or parallel according to the need of the renewable system (Pond, 2012; and Alkhalidi and Husein, 2018). 12V, 24V, or 48V batteries are recommended for home powering projects (Pond 2012). However, 12V deep cycle batteries were used in this study because they are the cheapest of the three and also the easiest to obtain (Pond, 2012). Batteries are one of the most expensive components in renewable energy systems and there are four major battery types that were considered for this project. While sealed batteries are more expensive and require less maintenance, flooded batteries are cheaper but require fluids replacement and seals checking (Pond, 2012). Gel batteries use a gelified electrolyte, which makes the resulting mass gel-like and immobile. Unlike a flooded wet-cell lead-acid battery, these batteries do not need to be kept upright *(Wikipedia,* 2019). But they are more expensive than sealed and flooded batteries. Also, at 80% discharge depth, AGM batteries will have about 400 cycles, while Gel will deliver 500 cycles (Victron Energy, 2019). However, apart from being smaller and much lighter in weight than other batteries, Lithium ion have higher density, improved resiliency, and longer cycle life of 1000 to 4000 at 80% discharge ('Connor, 2017). In this study, 12v lOOah lithium ion batteries was used, to get more cycle life out of the installation, and to make it lighter for staff to move it between the office and the home. The system in this is designed as a small stand-alone hybrid solar/wind energy conversion system (WEC), which is a suitable electricity supplier to an isolated situation (Kirsch, 2009) such as staff of the university need.

3.0 PRODUCING HYBRID SOLAR-WIND ENERGY SYSTEMS

In *Designing a Hybrid Wind and Solar Energy Supply System for a Rural Residential Building,* Hessami (2006) sought to provide a hybrid renewable energy system for the building's energy requirements, including a hot water service, space heating, and other electricity supply and storage systems. Performing a cost-benefit analysis for the building, the author found that it will be too expensive to heat up the large house on solar alone, because the house was designed with very large windows, which quickly decimated the indoor heat. Besides the heating requirements, power was also needed "not only for lighting but also for the operation of the airconditioner as well as various appliances that are normally used in the house" (121). This power need is definitely high, and the high expenses of a completely solar power system dwarfed the benefits and made it unfeasible to execute. This made a hybrid system inevitable for the project. Since the building's average power need for Summer and Winter was HKWh a day, the author used five 80w photovoltaic (PV) modules and a 2.5 kW output wind turbine generator. At the end of the design and installation, it was discovered that the final cost was much higher than connecting to the grid, that is, minus the intangible environmental benefits like reduced greenhouse gas emissions. While recognising that demand for more energy generates the search for newer sources and, Fesli, Bayir and Ozer, (2009) declare that wind and solar are the most popular because of their abundance, ease of availability and convertibility to the electric energy. In their work, *Design and Implementation of a Domestic Solar-Wind Hybrid Energy System,* sought to realize a solar/wind hybrid renewable energy system for a domestic application.

The project was implemented to allow the system's batteries to be charged by either wind power via a small alternator or solar power via an MPPT Module. The system was also designed to allow real time monitoring and control. As the authors explain, since photovoltaic solar panels and small wind turbines depend on climate and weather conditions, solar and wind power are often not sufficient alone. Thus, a number of renewable energy experts highlight the point that renewable energy projects are bound to be satisfactory if both wind and solar power are integrated within the system. In the summer time, for example, sun beams may be strong and wind velocity relatively small. At winter, sunny days are relatively shorter and wind velocity is often high. According to the authors, these disparities make solar and wind complimentary sources, meaning that there is more to be gained in a hybrid system than in a renewable energy solution in which only one of the sources is used. The point is that these two systems support each other to sustain the "continuity of the energy production in the system" (30).

In their work, *Design & Integration of Wind-Solar Hybrid Energy System for Drip Irrigation Pumping Application* Shivrath, Narayana, Thirumalasetty and Narsaiah (2012) have noted that there is increasing demand for the use of alternative and renewable energy sources to generate clean and low-cost electricity for agricultural uses such as water pumping. They also note the enormous potential for non-thermal onsite power generation in India, where people are increasingly investing is small-scale hybrid solar and wind power. To generate clean energy, while increasing energy independence for a rural agrarian uses, the authors designed and installed a renewable energy solar/wind hybrid system for a standalone drip irrigation system. Their product consisted of a submersible pump that drip irrigated 1.5 acres of mango crop. Their work provides a cost optimization of a wind-solar hybrid system, which outlines useful guidelines for small scale wind-solar hybrid system production. While they highlight the fact that solar-wind hybrid energy systems involve significant initial investments, the authors are convinced that the costs are competitive with conventional energy sources when a lifetime of reduced or avoided utility costs is accounted for. Furthermore, Shivrath, Narayana, Thirumalasetty and Narsaiah, (2012) note that the cost of the hybrid needs to be minimized to provide best value for the investor. They say this in the context that a "hybrid energy system helps in overcoming the drawbacks of the renewable energy sources and thus provides continuous supply of electricity" (2949). They conclude that solar-wind hybrid systems are the most feasible economic solutions for lowering electricity bills, while also helping in "avoiding the high costs of extending utility power lines to remote locations, prevent power interruptions, and provide a non-polluting source of electricity" (2950). In that sense, solar/wind hybrid system's major advantage is that when used together, the system is far more reliable and the battery storage size can be much reduced.

From the review of related literature, Hessami's (2006) main challenge was the volume of power needed for heating, refrigeration, hair dryer and other high-energy appliances like air conditioning, which significantly increased the resources and components required to configure the renewable system for the building. The energy needed for just lighting was minimal, feasible and easily achievable with a much smaller budget. Thus, the present study completely avoids the challenges Hessami (2006) contended with, because the hybrid system envisaged is merely for lighting and fan. Also, Fesli, Bayir and Ozer (2009) have j been able to demonstrate the complimentary and beneficial nature of hybrid wind and solar systems, in terms of being able to continuously generate the power output required of the system. Therefore, this validates the present study's objective of utilising solar and wind energies in the configuration. However, this study differs from Fesli, Bayir and Ozer's (2009) project in that, while theirs was a fixed installation, this is a mobile unit that can be used wherever the user is, whether office or at home or even in a remote village. To make the most of the solar/wind hybrid system being designed in this study, there shall be strict reliance on Shivrath, Narayana, Thirumalasetty and Narsaiah's (2012) summation that solar-wind systems are the most cost-effective renewable energy products. This will enable the research to produce a reliable solution and keep costs of a battery bank low.

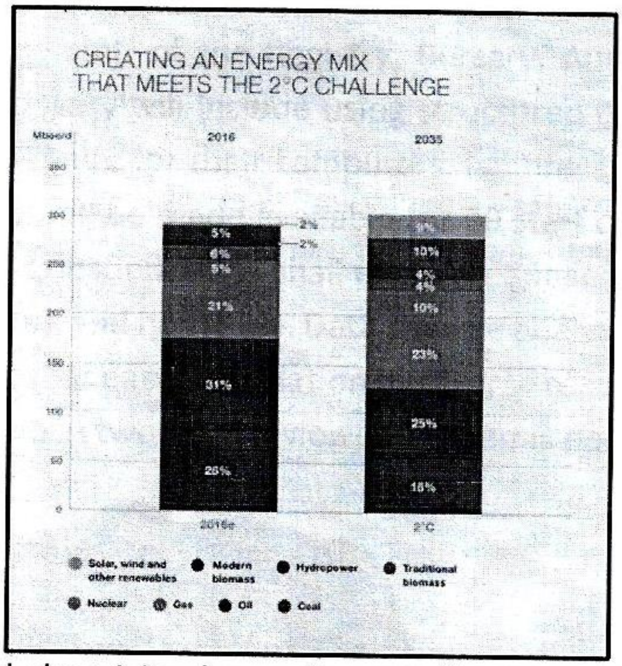

Fig. 6: Global electricity demands according to energy mix.

4.0 METHODOLOGY

The methodology for this research would be empirical, using industrial standard components and materials, to design and build two 500w and 1000w mobile hybrid wind/solar/mains renewable energy system that resonate with global energy mix (see: Fig.6) that can be used by staff of Cross River University of Technology. The casing of the designed prototypes is ergonometric and made of fibre glass with tyres at one end to make it light in weight, safe for handling, and durable for mobility (see Fig. 7). This research is essentially multidisciplinary and collaborative, in which a development economist and entrepreneurship scholar, a visual designer and an electrical electronics Engineer brought the methods of their disciplines together to resolve a daunting educational problem common in Nigeria's varsities.

Fig. 7: Tentatively called Greenpower, the hybrid system's casing shall be made of fibre glass, as the artistic impression above shows. When not in use, the solar panels shall be stowed in a slot in the devise's body.

The study area is the Calabar Campus of Cross River University of Technology, with 10 academic faculties and where most of the staff of the Registry, Bursary, Audit, Security and Domestics departments work. The methodology was eclectic using structured questionnaires and semi-structured in-depth interviews to assess the average minimum power members of staff require for their computers, lighting and fan points. At the end of the production, the prototypes were made available for 20 staff of the university to use for a day each. Subsequently, responses were elicited to verify, collaborate, and clarify the impact of the system on their work and home life. Data was analysed with SPSS and presented in charts, graphs and percentages for easy assimilation by diverse readers, as well as determined the model that best suits the purpose.

5.0 CONCLUSION

"The alarm bells are deafening, and the evidence is irrefutable: greenhouse gas emission are choking our planet and putting billions of people at immediate risk. Global heating is affecting every region on Earth, with many of the changes becoming irreversible"
(**Findings from the UN Climate Change Report 2021**)

The case for a shift from fossil fuel energy regime to renewable technologies in Nigeria's energy architecture is not only compelling but also urgent. Oil and gas are Nigeria's strategic minerals, but prone to dilemmas, finite, ironies, provokes growing concerns about climate threat and health, and exacerbates conflict in the Niger Delta region of Nigeria (Takon, 2013). The conclusions developed in this paper would enhance and sustain the direction of public energy policy in Nigeria in particular and developing economies in general in the face of pressure to reduce greenhouse emission amid a growing demand for power.

I argue that dependence on fossil fuel and consequences arising from climate change, as well as the attendant energy poverty compels interests in green energy technologies, such as off-grid power in Nigeria's tertiary institutions and rural communities. The latter is where 70% of the country's population resides. Though the alternative energy technologies are fraught with limitations, energy from oil resources are becoming more undesirable based on global interest in cleaner and more efficient combustive energy from renewable sources. To this extent, International bodies, like the Kingdom of the Netherlands' energy scheme in partnership with the World Bank did set up in 2009 the Africa Renewable Energy Access (AFREA) programme to help meet "Green energy" needs in African countries, such as Nigeria. That said, this project and research meets both tangible and academic outputs, respectively. First, two functional prototypes were produced, of the mobile hybrid wind/solar/mains renewable energy system that staff of the university can use for their work at the office and at home using identical casings, one prototype is 500w, and the second 1000w to reflect two basic energy needs.

Second, to make the research findings available to other scholars and others in Nigeria and beyond. Finally, though current renewable energy policies are evolving and require time to be well-rooted, Nigeria's supportive environment, growing technical capacity and potential for strong supply chain ideally places the country sustainably and competitively on the continent of Africa's emerging energy ecosystem.

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