Investigating the Penetration Rate of Electric Vehicle in Developing Countries: Nigeria as A Case Study

Abubakar Bawa, Mark Ndubuka Nwohu

Abstract— **The concept of electric vehicles has been widely accepted by people all over the world, and sales are expected to continue to rise. Electric vehicles (EVs) are gaining traction in Nigeria as well. Furthermore, through a bidirectional charging system, the deployment of electric vehicles in Nigeria can support environmentally friendly renewable energy development. Electric vehicle development could also lower emissions, reduce energy sector investment, and potentially eliminate the need for costly petroleum subsidies. The benefits are obvious, however, Nigeria's challenges that will impede high rate of penetration hinge on the epileptic electricity supply. This investigational assessment has recognized the enormous potential of electric vehicles in Nigeria as an improvement and advancement agent. With the entire vehicle industry looking for new learning and development opportunities, it is reasonable to anticipate that those open opportunities will significantly increase in Nigeria, the continent's largest economy. Ideally, with the right methodologies, strategies, perspectives, policies, and commitment, the future of electric vehicles in Nigeria appears to be clear. To that end, this paper assessed the penetration rate of electric vehicles in Nigeria, considering the potential impact of EVs on the country's auto industry.**

Keywords— **Electric vehicle, Prospect, Renewable energy, Battery, Nigeria**

I. INTRODUCTION

Battery electric vehicle penetration of U.S. households overall is roughly 2% today. The U.S. industry is still in the Model T phase of EV adoption. Norway has the highest market penetration per capita in the world, and also has the world's largest plug-in segment market share of new car sales, 86.2% in 2021. By June, 2022 China was able to produce 10 million plug-in EVs that were on the road and on September same year U.K. flanked 1 million plug-in EVs [22]. Europe is forecast to overtake China and have the highest penetration rate of EVs use in the world by 2030 according to the Citi State of Global EV Adoption report. Actually, China has a penetration rate of 66.6%, South Korea has 60.5%, US has 45,8% while the middle East and Africa are forecast to have a penetration rate of only 2.7%. The EVs market worldwide is projected to grow by 17.02% (2023-2027) resulting in a market volume of US$ 858.00bn in 2027.

Concerns about the limited supply of fossil-based energy are causing serious movement in the search for alternative modes of road transportation. Similarly, regulatory tensions or pressures to reduce urban pollution, CO_2 emissions, and city noise have made module electric vehicles [1] an exceptionally appealing choice as an alternative to the internal combustion engine [2]. It is in contradiction to this background that the novel upswing of electric vehicles in Asia, Europe, and America, as a substitution for conventional fuel-powered vehicles, turned out to be pertinent to the Nigeria and a convincing issue for research. Electric vehicles are not exactly a new oddity. The report noted that transportability would soon change dramatically as EVs proliferate, ride-sharing continued to grow, and eventually, autonomous vehicles (AV) would enter metropolitan armadas. This was especially true for urban communities where innovative forms of transportation are exceptional and where investment or interest in the enabling environment is expected to guarantee this development. Furthermore, as representatives seek to address fuel emission concerns, automakers are beginning to phase out vehicles powered solely by petroleum products known as fossil fuels [4].

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II. CONCEPT OF THE ELECTRIC VEHICLES

A. Automotive Industry

The term automotive is derived from the Greek expressions auto, which means "self," and motivus, which means "of movement." It is thus associated with self-moving vehicles or machines. [5] defined the auto industry as "all associations and exercises concerning the manufacture of engine vehicles, including parts such as engines and bodies, but excluding tyres, fuel, and batteries." Generally, vehicle production has advanced around the world since around 1886, when the first modern vehicle was licensed or patented by German inventor, [6].

Before then, Scottish inventor Robert Anderson created the first rudimentary electric vehicle, which ran on nonbattery-powered necessary cells between 1832 and 1837 [7]. Production methods, quality assurance, manufacturing frameworks, computer-aided design, branding, business mergers and acquisitions, and globalization have all undergone enormous advancements since that time. Because it serves as a considerable upgrade for various types of assembly activities, the automobile or car industry is seen in any economy as a significant tool for socioeconomic and technological evolution [8]. The automotive industry supports upstream ventures or industries (mining, oil, gas, steel, metals, and plastic), core auto industries involved in actual equipment and component manufacturing, and downstream industries (monetary administrations, sales, marketing, etc.). Natural substances used in automobile assembly come from a variety of industries, including glass, aluminum, iron, steel, plastics, covering, central processors, and much more. The automobile industry is regarded as a

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cornerstone of the global economy. It is also a significant driver of macroeconomic growth, stability, and technological development in many developed and developing countries.

B. Electric Vehicles

An electric vehicle (EV) is a device that uses one or more electric motors to provide thrust. Depending on the type of vehicle, movement may be provided by wheels or propellers driven by rotating motors, or in the case of tracked vehicles, by linear or straight motors [7]. To run the electric motor on this car, it uses enormous traction batteries. There are times when the battery pack needs to be charged by plugging it into a charging station or wall outlet. The exterior of an electric car is noticeably different from a vehicle fueled by petrol because it is powered by electricity.

The rising need for eco-friendly, high-performance, and low-emission automobiles gave rise to interest in electric vehicles. Growth in the market is also being driven by a trend toward a reduction in vehicular emissions as a result of strict guidelines and legislation in some nations.

The fantastic infrastructure for public charging that has been built in industrialized countries like China, France, and Norway is another factor. However, the comparatively high cost of electric vehicle assembly is a key barrier to the market's expansion.

According to a study of EV well-to-wheel emissions, E4Ws and HEVs reduce CO_2 emissions, but they may emit more PM_{10}, SO_2, and NO_X in the air than an ICEV engine if the electricity mix is predominantly thermal [9]. According to the findings of that study, HEVs perform better in countries with unclean electricity mixes, such as India and China. Furthermore, zero-emission benefits will be impossible to achieve unless these particulate matters are controlled. Furthermore, efforts should be made to make the electricity mix as green as possible in order to control the negative externalities associated with EVs [9]. Resale Issue is another limitation, Consumers typically reject novel and untested technologies in their environment. According to a study, consumers' perceptions of risk can influence their decision to buy new products. Experience, emotions, nontechnical sources, and the media all contribute to the formation of this risk perception. Media and social networks may alter values that influence consumer choices. Due to uncertainty and the worry that the public good would surpass the company's private good, private business owners can occasionally be reluctant to accept new technology, such as EVs [9].

i. Electric Vehicles challenges and mechanical advances

Batteries are an essential component of electric vehicles due to their high cost and direct impact on vehicle performance. Lithium-ion batteries have been replaced by a more long-lasting innovation that is remarkable, powerful, and efficient than current models.

- Iron phosphate is the synthetic structure of lithium-ion (LiFePO4). The battery's high energy density and long-life expectancy are two of its most notable characteristics [10].
- Magnesia ionized as Mg2+ (Mg-Ion). Because lithium is filled or substituted for magnesium in the manufacture of these lithium batteries, they have twice the capacity and multiple times the steadiness or stability of their magnesium counterparts. Unlike today's best lithium batteries, which have an energy density of only 0.735 kWh/L, this battery is expected to have an energy density of 6.2 kWh/L. • Metal lithium. On the anodes of these batteries, a delicate lithium metal layer replaces the graphite layer. These batteries have twice the energy density of a standard lithium battery.
- Air-aluminum. In batteries, oxygen and aluminum are combined to produce electricity.
- The grapheme. Carbon is used to create graphene, a delicate, light material with excellent thermal conductivity. Grapheme-based batteries can be charged quickly or ultrafast without incurring significant power losses due to heat accumulation. The Spanish startup graphenano has created an electric vehicle that can travel 800 miles on a single charge [11]. Materials made of graphene have a high surface area, high porosity, and are incredibly strong and light. These materials are useful for energy storage because they have high charging capacities, are flexible, and effectively conduct both thermal and electrical energy. Graphene's strong electrical conductivity boosts electrode density and speeds up chemical reactions inside batteries, resulting in greater power transmission and faster charge rates with less heat.
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III. TYPES OF ELECTRIC VEHICLES

According to the Australian Electric Vehicles Association, there are three major types or classes of electric vehicles (EVs), depending on how much electricity is used as their energy source [12] Text Font of Entire Document

A. Hybrid Electric Vehicles (HEVs)

These vehicles are propelled by both gasoline and electricity. On this occasion, electric energy is generated by the vehicle's braking mechanism, which re-energizes the battery, and this is referred to as "regenerative braking." HEVs start by using an electric motor; as the speed or load increases, the petroleum engine kicks in. The two motors are constrained or controlled by an internal computer framework that ensures the best economy for the driving conditions.

B. Module or Plugin Hybrid Electric Vehicles (PHEVs)

These vehicles, also known as Extended-Range Electric Vehicles (EREVs), are powered by both electricity and petroleum. The battery is recharged by regenerative braking and plugging into an exterior electrical charging outlet. In EREVs, the gasoline engine covers the vehicle's range of motion while also recharging the battery as it depletes.

C. Battery Electric Vehicles (BEVs)

These are entirely electric vehicles because they are powered solely by electricity and lack any petroleum engines, gas tanks, or fumes pipes. Plugin EVs charge their batteries via external electrical charging outlets or sources.

Regenerative braking can also be used to recharge BEVs. In terms of comparison, the most discussed and widely used variant is the BEV, owing to its technological and mechanical advancements and ease of use with low pollutants.

IV. PRESENT STATUS OF ELECTRIC MOBILITY IN THE GLOBE

According to a review, 65% of all buyers of electric fourwheel drives (4WD) are in the United States and China. Europe, which accounts for 23% of the global stake, is in second place [11]. In 2016, six nations sold more than 1% of all passenger light-duty vehicles (PLDVs) with an electric

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four-wheel drive system. With a 29% Electric 4WD markets share in its PLDV stakes, Norway was unquestionably the global leader when these nations were considered [13]. Norway achieved this result as a result of recent environmentally conscious policies and strategies that included a wide range of motivators or incentives, tax cuts, and the elimination of tolls for electric four-wheel drive [14] et al., 2016),[15]. Norway, Sweden, and the Netherlands have the largest Electric four-wheel drive markets, with 3.4% and 6.4% PLDV shares, respectively. The majority of electric vehicles enrolled in the Netherlands, Sweden, and the United Kingdom are plugin hybrid electric vehicles (PHEVs). China and France primarily have BEV markets; in 2016, 75% of electric vehicles sold were Electric 4WD, while 25% were Electric 2WD (PHEVs). However, in Japan, Norway, and the rest of the world, electric vehicle sales were roughly split between Electric 4WDs and PHEVs [13].

V. THE NIGERIA SITUATION

According to information released by the international automakers' association, Organization Internationale des Constructeurs d'Automobiles [16] Africa as a whole produced roughly 831,000 vehicles in 2014, or less than 1% of the world's total vehicle output. The majority of these outcomes were South Africa's responsibility. Morocco, Algeria, and Egypt were in second place. Behind countries like Algeria, Morocco, South Africa, and Egypt, Nigeria had Africa's fifth-largest automotive market in 2013. These numbers don't include early assembly activities in different Sub-Saharan African nations.

Vehicle manufacturing is almost non-existent in the region or continent, with the exception of South Africa and a few North African countries. The largest plant in Africa is Renault's 400,000 vehicle per year volume plant in Morocco, which cost €1 billion to build. A large portion of its output is destined for export to the Middle East, Europe, and North Africa [16].

Act No. 83 of May 30, 2014, which merged the National Automotive Council and the Center for Automotive Design and Development, created the National Automotive Design and Development Council (NADDC) to address the sharp drop in the Nigerian car sector. It became a subsidiary of the Federal Ministry of Industry, Trade, and Investment [17]. The resuscitation of the auto sector is a key objective of NADDC. The NADDC estimates annual vehicle imports at roughly 400,000 units, or 100,000 new and 300,000 used, valued at about US$3.45 billion. Nine (9) companies are set up to manufacture cars in Nigeria, and the local production volume of vehicles is estimated to be approximately 100,000. Nevertheless, utilization has decreased over the years to less than 15% of the installed limit. Industry experts concur that Nigeria's potential annual new car market might include about 1,000,000 units. Although the market is dominated by used cars, the current import of new vehicles is only about 56,000 [17].

The majority of vehicles assembled locally in Nigeria are Chinese models assembled by Innoson Vehicle Manufacturing Company and the new beginning of production of the Nissan Patrol by the Stallion Group, despite Peugeot Automobile Nigeria Limited's plans to start production of the Peugeot 301 brand soon. Nigeria is primarily a used vehicle market, with a new-to-fairly-used (tokunbo) vehicle ratio of around 1:134 [18]. Tokunbo vehicles are imported from the United Kingdom, the United States, Germany, or via Cotonou in neighbouring Benin Republic by tokunbo vehicle vendors, independent sales representatives, and individual purchasers. EVs are not yet present on Nigerian roads. A remarkable action should be taken to ensure that Nigeria is not abandoned or left behind as this is the direction the rest of the world is watching. Nigeria should deal with this important problem. By supporting the Electric Cars (Introduction) Bill 2019 in the legislative house, Nigerian Senator Ben Murray-Bruce has brought attention to the issue of electric vehicles. The legislation focused on phasing out gasoline-powered automobiles and introducing electric vehicles by 2035.

The Bill was defeated on the Senate floor after various arguments were raised against it by lawmakers. Some of the reasons include the difficulty in implementing the discontinuation of the use of internal combustion engines (ICE) and the adoption of electric vehicles, which would harm the economy; Nigeria is a major oil producer. Notwithstanding the difficulties unsettling the auto sector in Nigeria, a few assemblers have shown attentiveness in putting resources into the assembling of electric vehicles (EVs). Throughout the long term, experience has shown that Nigeria generally ends up being an unloading ground for various banned items or products. The country remains at a higher risk of dumping when the different country at last stage out the utilization of traditional fuel vehicles. Because the majority of people in Nigeria have extremely low purchasing capacity, they tend to prefer secondhand cars than immaculate or brand-new ones. It is nonetheless significant that a local or indigenous company, Nigus Enfinity, has expressed interest in entering the Nigerian auto industry in 2018 with electric vehicles, even though its local assembly factory for EVs was anticipated to open in 2020 [19].

A. Prospective Impact of Electric Vehicles in Nigeria

the introduction of EVs into the Nigerian auto industry will undoubtedly have a number of consequences, the most notable of which are as follows [8]:

i. Impact on Crude Oil Production

According to data from the Nigerian National Petroleum Corporation, 24.4 million barrels of crude oil were imported by the UK, Netherlands, France, India, and China for the entire month of May 2017—nearly half of the nation's total exports. As part of their efforts to reduce pollution and fossil fuel emissions in their countries, these countries are now developing plans to discontinue the use of petroleum-powered automobiles, which is significant. This will influence Nigeria's oil export in years to come. All the more as of late, the UK lined up with France in declaring that new fuel-powered vehicles would be prohibited by 2040, to urge users to switch over to electric and hybrid vehicles. One of the greatest importers of Nigeria's crude oil, India, is thinking about plans to help electrify all vehicles in that country by 2030 [8].

ii. The influence on government revenue Nigeria's oil revenues, which as of the end of 2018[20] accounted for more than 87.7% of the country's foreign trade profit, will be in jeopardy. The international acceptance of EVs will

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undoubtedly have a negative impact on government revenue given the nation's mono-social economy. There will be long-term economic repercussions of this development.

iii. Repairs and Maintenance

Electric vehicles are less expensive to operate and maintain because they have fewer moving parts. The market for maintenance and spare parts services will contract as fewer things go wrong. This will have an impact on the country's vehicle maintenance and services sector. Electric vehicles have fewer mechanical parts, which implies that replacement costs will be lower. Furthermore, because electric vehicles do not have an engine, there will be no need for routine filter and oil changes, making them significantly simpler to acquire and maintain when compared to gasoline-powered vehicles.

iii. Climate Change

EVs will have a significant impact on slowing the pace of environmental change by assisting in the elimination of CO_2 emissions, thus improving air quality. Because of the use of non-renewable energy sources, global warming has recently become a worldwide concern. The risk of global temperature change will be reduced by using EVs or "green vehicles.

iv. Public Health

The introduction of electric vehicles will further improve public general well-being or health because one of the most serious negative consequences of ICEs is fume emissions. These fumes stink, are filthy, and contain dangerous gases. Contaminants found in vehicle exhaust emissions can cause serious unexpected health problems such as asthma and bronchitis, while synthetics such as carbon monoxide and benzene block oxygen from entering the body's vital organs and may contribute to the causes of certain types of harmful illnesses.

B. Challenges Facing Introduction of Electric Vehicles in Nigeria

The following are considered to be the key challenges that EV adoption will present [8].

i. Availability of power

This is the critical test or challenge that the introduction of electric vehicles in Nigeria will have to face. Nigeria's power generation, transmission, and distribution networks are in disrepair. The regular power outages that the country is accustomed to cannot bode well for self-motivated EV use. The most recent significant peak normal power supply was in July 2022 at around 4, 022.2MW, while off-peak generation in the same month was estimated at 3,521 MW for a population of over 200 million people. This challenge becomes clear when one considers what is going on and the fact that South Africa, Africa's second largest economy, generates over 40,000 MW of energy for its 62 million people.

ii. Charging Facilities for EVs

This can range from thirty minutes to twelve hours depending on the capacity of the battery and the charging station's speed. Several organizations are currently investigating cutting-edge quick chargers, which are capable of recharging EVs with a range of 200 to 300 kilometres in a reasonable amount of time. Various charging innovations, such as remote or wireless charging pads in parking areas, wireless charging under streets, and solar-powered rooftops, are being planned and designed. Previously, EVs faced a significant challenge in that they required battery replacement stations every 30 kilometers or so. Notwithstanding, fast improvements in battery innovation that favour electric vehicle has positively advanced the circumstance.

iii. Telecommunications

Further developed telecommunications innovation and expanded networks raise the significant question of whether it is even necessary to own or make specific trips that may be deemed unnecessary. A multi-tier heterogeneous network that incorporates several vehicular communication technologies is advised in Nigeria in order to address the various communication needs of various use cases. This network should also incorporate various network technologies and software-defined networks (SDN). The architecture of these hybrid networks can be set up either hierarchically or flatly. Each entity in a network that has a hierarchical architecture belongs to a certain level, and communication between entities at various levels and between groups of entities at the same level involves using a certain technology. As an alternative, in flat topologies, the type of data being communicated or other performance parameters are used to determine how the nodes will communicate with one another.

iv. Environmental Concerns

While it is acknowledged that the introduction of electric vehicles will reduce CO_2 emissions, there is also the environmental issue of battery disposal and manufacturing, which may be difficult in Nigeria, where the ordinary domestic waste administration framework is already a source of concern. These batteries are complex because they contain poisonous synthetics, making their disposal near the end of an EV's life a significant environmental challenge.

C. Choices and needs for the future

Accelerating the deployment of electric vehicles in Nigeria will necessitate strong non-financial policies and actions. Nigeria can now concentrate on the following processes:

i. Draw from the experience of friends

East African countries, particularly Kenya, are now investing heavily in two and three-wheeler EVs because they are less expensive and easier to adopt. Nigeria has a moderately large supply of two-wheelers known as Okadas and three-wheelers known as Keke-Napeps, which are primarily used for intra-city business transportation. By focusing on these types of EVs, Nigeria could quickly test the viability of EVs in the country. Presenting more modest EVs initially can in any case help with the advancement of various charging stations in urban and rural areas, reducing the charging infrastructure gap when four-wheel EVs become common.

ii. Tap into the used or pre-owned EV market

Importing used vehicles from various countries is one method for lowering the upfront cost of electric vehicles. EVs emit no tailpipe emissions regardless of how long they are in use, as opposed to ICEVs, which have more emissions over time and without maintenance. Nigeria could use its previous system for used vehicle importation to speed up the importation of used EVs into the country.

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iii. Explore ingenious financial incentives

High import duties are a major cause of low vehicle acquisition in Nigeria. Financial incentives, such as the removal of import duties, a VAT, and reduced vehicle insurance for electric vehicles, could make electric vehicles more appealing and affordable to Nigerians.

iv. Present creative business model or plans of action for charging infrastructure

The Nigerian government is currently overburdened with the obligation of providing essential electricity access to large numbers of people who do not have access to modern energy services. In any case, the government can make the charging infrastructure market more accessible in order to encourage private-sector collaboration. Experiences from innovative plans of action used to accelerate mini-grid development in the country can be applied to the electric vehicle charging framework to make it suitable for venture capitalists, customers, and the government.

v. Foster a far-reaching EV policy

While Nigeria's automotive policy encourages domestic production and supports domestic vehicle manufacturers; it is silent on EV advancement. To begin any meaningful discussion on EV deployment in Nigeria, the government must lay out a robust EV policy system with targets and guidelines supported by a suitable act of parliament.

vi. Create organizations for EV training in Nigeria

To increase public acceptance of electric vehicles, oil companies, legislators, ICEV mechanics, and the Nigerian people all require more reliable information. Reliable EV instruction or training and education are expected to avoid potential fear and misrepresentation of the potential disruptions and benefits that electric vehicle could bring to the conventional vehicle market and the country economy at large [21].

VI. CONCLUSION

Nigeria is both the most populated Black country and the continent's largest economy. With these two credits, Nigeria is more receptive to the positive effects of innovation and technological growth. However, Nigeria has the greatest number of poor individuals per capita in the entire globe. This poverty level obstructs Nigeria's attempt to be the forerunner in African development actions in innovation, agriculture, technology, and trade. With so many challenges in infrastructure, security, and overreliance on petroleum, the future of electric vehicles in Nigeria is truly uncertain.

This investigational review has highlighted the enormous potential of electric vehicles in Nigeria as a means of improvement and development. Electric vehicles will undoubtedly change the way Nigerians work, exercise, and travel. It will lower costs while also contributing to a cleaner environment and other benefits. With the global automotive industry looking for new learning and growth opportunities, it is reasonable to expect those opportunities to settle in Nigeria, the continent's largest economy. Expectantly, with the right approaches, policies, perspectives, and accountability or commitment, the eventual fate of electric vehicles appears to be vivid in Nigeria.

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