Drivers of Smart Grid Technology in Ghana

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***Abstract*—Smart Grid technology (SGT) is regarded as a key element for efficient use of distributed energy resources with the ever-increasing price of petroleum products and climate change the world is currently facing. The difference in electricity generation is desired to fight climate change and increase energy security in the world. The study sets out to examine quantitatively, the drivers employed in the implementation of SGT among critical stakeholders in Ghana energy sector. The results show that regulatory, operational, market, environmental, security factors significantly influence SGT implementation in Ghana. This research outcome will provide a theoretical basis and simultaneously can be used to analyses SGT implementation. From a managerial perspective, this study identifies critical drivers essential to successful SGT implementation in Ghana.**

***Index Terms*—About SGT, renewable energy, drivers, Ghana**

I. Introduction

Supply of a reliable, adequate and economically priced power supply is vital for the socio-economic development of Ghana. It has been noted that the growth rate of the Ghana population has a direct relationship with the growth in the per capital electricity consumption [1]. The importance of energy to the Ghana economy cannot be denied; it is underlying currency vital to the economic prosperity of the citizens. The population growth has already raised concerns over supply difficulties, exhaustion of energy resources and substantial environmental impacts [2].

Ghana has a legally binding target of delivering 15% of all energy from renewable sources by 2020, and of reducing Greenhouse gases GHG emission by 80% by 2050, with a reduction of at least 34% by 2020 and a target to achieve 9% energy savings by 2019 [3]. Africa's primary electricity use is expected to increase from 505 TW in 2007 to 1012 TW in 2030.

Explored drivers encouraging renewable energy (RE) in the European Union (EU) and recommended that both the lobby of the traditional energy sources and CO_2 emissions restraint deployment of RE, whereas the objective of reducing energy dependency stimulates RE use [4].

There is considerable literature suggesting that legal drivers, such as regulations and policies, are a useful tool in encouraging energy efficiency and environmental performance [5]. A great lack of understanding exists, moreover, regarding the main factors that drive this clean energy technology. Studies to date are not consistent and do not investigate the full spectrum of drivers, but rather focus more on common.

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II. THE CURRENT GHANA GRID

Ghana's electric grid generally uses old technology, not having incorporated new digital technologies extensively. Digital technologies have transformed various industries, which include telecommunications. The ageing of power systems induces a replacement wave of electrical infrastructure in the coming decades [6]. A similar transformation has not yet occurred in the electric grid. The current grid lack the capacity of supporting continued information flow [7], [8].

The electricity generation from certain relevant renewable technologies fluctuates based on the availability of variable resources [9]. The current grid cannot support levels of variable renewable generation over, roughly, 20% of energy. Ghana grid has limited support for distributed generation, since it has been designed for one-way power flow from centralised power stations to end users; it has to be upgraded to allow a two-way power flow that supports small-distributed generators. To this end, enhancing the ageing power system towards the smart grid is imperative by integrating efficient communication infrastructures with power systems timely [10], [11], [12].

SMART GRID TECHNOLOGY (SGT)

While expanding and developing the grid to meet the growing demand remains a challenge in future electricity grids, new clean technologies that will reduce the CO_2 emissions and the current dependency on carbon-based fuels have been investigated lately [5]. Smart grids are generally perceived as the solution for the many challenges for old electricity systems and the pathway to allow carbon electricity economy [13]. The SGT is a system that optimises power supply and delivery, minimises its self-healing losses, and enhance demand response applications and energy generation efficiency. An SGT entails various blocks, such as an open standard for communications with devices – both transmission and distribution (T&D) and end-use accessories for advanced metering infrastructure (AMI)

[14].

Some governments, such as the United States and some European countries [15], actively sponsor smart-grid implementations. Smart grid deployment has been aggressively pursued with sponsorship and involvement from government, businesses, utilities and other stakeholders to bring additional knowledge combined with advanced information technology to the power grid, which is more reliable and secure [16].

The future electricity grid not only promises to be a radical technological, environmental and economical upgrade of the old system, it will also be a more pervasive technology, influencing the daily life of users [17]. SGT provides quality power that meets 21st-century demand, which cooperates generation and storage options that fulfil customer's needs considering the changes and the challenges.

The critical goal of SGT is to promote active customer participation and decision-making, as well as to create the operating environment in which both utilities and electricity users influence each other [18].

The concept of an SGT encompasses the entire electric power delivery system, beginning at the output of all generation sources and extending to the final use of the delivered energy. Ghana SGT infrastructure will evolve as a highly automated and interconnected network where information and knowledge will flow through intelligent systems to serve the entire grid community, enabling the growth of the national economy [19].

This paper provides a thorough literature review on the concept of SGT technology and the drivers to the adoption of SGT, as no study has been carried out in the Ghanaian context to indicate the critical drivers of SGT technology implementation.

III. DRIVING FORCES FOR SMART GRID TECHNOLOGY IMPLEMENTATION IN GHANA

Different types of factors that stress investments in clean energy technologies are both energy efficient and cost-effective. Figure 1 shows the diagrammatic presentation of various driving factors of SGT's implementation, such as regulatory, operational, market, environmental and security factors.

IV. OPERATIONAL DRIVERS

Confronted with the need to advance operating efficiencies further, utilities must deal with challenges associated with an ageing workforce, and expectations for flexibility and developed services by regulators, customer and the market place [19].

The goal of operations management is to maximize net firm value by acquiring resources and configuring processes such that the resulting organizational capabilities are aligned with the competitive position of the organization and the various clean energy operational elements, discussed below.

i. New infrastructure: It has been perceived that the current electrical grid is outdated for modern electricity delivery, as it wastes much of the generated power (Seal, 2008). There has been no significant investment in the transmission and distribution infrastructure, and there is an escalating need for new communications, energy, security, and computing/information technology infrastructure to enhance the delivery of reliable and secure power in Ghana energy sector [20].

ii Simplicity: Ghana energy consumers are ready to engage with the SGT as long as their interface with the SGT is simple, accessible, and in no way interferes with how they live their lives. SGT will be simple, “set-it-and-forget-it” technology, enabling Ghana consumers to adjust their energy use easily.

iii Reduced Transportation Requirements through Automated Meter Reading: This reduces transportation needs, leading to less fuel consumption and fewer carbon emissions [21].

iv. Accelerated Innovation in Devices through Open Standards: A SGT will promote open standards and interoperability among the components of the communications, as well as among the smart and efficient end-user devices connected to the grid. The open standards will likely encourage firms to invest more capital in intelligent and capable end-user tools.

v. Enhanced Customer Service: An SGT will also enable utilities to offer an expanded portfolio of services to customers, through improved customer service, helping consumers to better participate in the market not only by using their energy more efficiently but also by allowing consumers to act even as producers selling back their excess electricity [22].

vi. Operational Efficiency: Similarly, increased visibility into supply and demand can help reducing bottlenecks and grid congestion, for more efficient operation and maintenance. SGT will enable several operational benefits for utilities, which include advanced distribution management functions, outage management, as well as an automated change of service, improved asset management capabilities, more exceptional load profiling ability and grid stabilisation [23].

V. MARKET DRIVERS

Design of future electricity markets is aimed at providing their consumers with highly reliable, flexible, readily accessible and cost-effective energy services. SG offers new business opportunities for different kind of industries, such as smart-meter vendors, electric utilities and telecom operators from all around the world [24].

SGT operations, upon appropriate deployment, can open up new opportunities with significant financial implications. SGTs can continue towards enhancement of the power market, status of the power market, as well as initiations of SGTs in potential power market enhancement with the advent of SGTs. Despite studies that consistently support that a large number of consumers express a willingness to pay for green products, the investors are primarily concerned about the demand side of a technology project and related rate of technology diffusion because they may have to make a substantial up-front investment for a long term return. The items that describe market drivers are outlined below.

i. High Demand: As the internal market develops, the population explode; every part of the nation does electrification. The supply and demand for electricity would have been skyrocketed through the computer revolution, growth of the internet, and proliferation of electronic devices [25].

ii. Application of customers and utilities: Consumers will have the opportunity to see what price they are paying for energy before they buy a powerful motivator toward managing their energy costs by reducing electric use during peak periods [26]. Facilitate Enhanced Developments in communications, metering and business systems will open up new opportunities at every level on the network to enable market signals to drive technical and commercial efficiency

iii. Advanced electricity service and solution providers: This encourages new businesses and generation options, including sales of surplus to the grid and the purchase of electricity from supplier companies. Dynamic pricing will give the customers an economic incentive to decreased loads during peak periods and special peak events (e.g. Critical Peak Pricing) when electricity rates are higher [27].

iv. Affordability: For a smarter grid to benefit society, it must reduce utilities' capital and operating expenses today or reduce costs in the future. Energy prices will rise; however, the trajectory of future cost increases will be far more gradual for post-SGT. SGT technologies, tools and techniques will also provide customers with new options for managing their electricity consumption and controlling their utility bills.

v. Energy Savings Powered by Information: Energy savings can also be achieved when consumers know how their activities contribute to their overall energy use and consequently make changes in their energy-consuming choices [25]. The functional advantage of advanced metering permits utilities to send customers frequent, accurate and informative billing that comprises comprehensive energy usage data. Invoice of this nature can inspire changes in the behaviour of consumers, often yielding significant energy savings [28].

VI. REGULATORY DRIVERS

The clean technology industry is not immune to the adverse effect of the lack of policy and regulations on the pace of technology development and deployment. The regulatory uncertainty addresses the unpredictability of a firm's regulatory environment. The regulatory framework concerning clean SGT their progress due to not only unestablished policies and regulations but also the need to replace the existing rules [24]. The items that describe regulatory uncertainty are best represented as price setting, technology standards and quality, financial practices, labour laws, marketing and distribution laws, and accounting law. To reduce their dependence on imported fossil fuels and to be in line with Kyoto targets, the European Commission (EC) proposed Directive 2009/28/EC [29]. Notwithstanding commercial business prospects and a sizeable impending market, tangible investments in energy-efficient technology have not grasped economically optimal levels.

Regulatory Drivers, national and regional regulations and policies have a profound impact on a fundamental, universal comprehension of the needs of the nation's energy providers and consumers. A stable and precise regulatory framework, with well-established and harmonised rules across Ghana, should support Ghana's smart grid market and related services [30].

Regulatory structures should align incentives that secure a grid with increasingly open access. A survey showed that Kyoto targets and United Nations Framework Convention on Climate Change (UNFCCC) as the highest in the policy-related drivers; and that follow by Ghana energy sector reform program and the lowest as Ghana Electrical Appliance Labelling and Standards Programme (GEALSP).

VII. ENERGY SECURITY

Power utility companies worldwide lose about 20 billion dollars each year because of non-technical losses. Further, the growing non-technical losses due to theft and billing irregularities force the utility companies to implement a transparent and genuine metering system [31], [32]. Threats to energy security include the fossil fuels, the manipulation of energy supplies out of the political instability of some energy-producing nations, the competition over energy sources, attacks on supply infrastructure, as well as accidents and natural disasters [33]. One of the main threats to energy security is the significant increase in energy prices. Markets have occurred in several energy crises over the years, along with the imposition of price increases by the supplier. The items that describe energy security are outlined below.

i. Security: The SGT will be more resistant to attack and natural disasters. So fortified, it will also move us toward energy independence from foreign energy sources, which themselves may be targeted for attack [34].

ii. Increased reliability and security: Advanced communications networking technologies and real-time monitoring capabilities provide power companies with increased, end-to-end visibility to resist both physical threats and cyber-attacks. Networked operations also improve reliability and minimise costly downtime.

iii. Safety: The modern grid improves safety, protecting workers and the public alike. It mitigates the hazards of interconnecting large numbers of diverse generating sources and energy storage devices.

iv. Resilient: Increasingly resistant to attack and natural disasters, as it becomes more de-centralised and reinforced with SGT security protocols [35].

v. Quality of Supply: The ageing infrastructure of Ghana electricity transmission and distribution networks is increasingly threatening the quality of supply. The new grids provide consistent and reliable power quality, capable of delivering the necessary power quality, free of sags, spikes, disturbances and interruptions.

vi. Intelligent: Capable of sensing system overloads and rerouting power to minimise or prevent a potential outage. It works autonomously and faster, cooperatively in aligning the goals of utilities, consumers and regulators.

VIII. Environment security

Despite the many forces pushing Ghana towards grid modernisation, environmental issues have moved Ghana to meet set targets. The greenhouse gases are recognised as one of the most significant economic and ecological challenges facing humanity under the Kyoto Protocol and beyond. Today, utilities must also address mitigating emissions of greenhouse gases, mainly carbon dioxide (CO_2), to curb global climate change and its impact. This has far-reaching ramifications for the future of the grid [36].

While the nation's transportation sector emits 20% of all the carbon dioxide, the generation of electricity emits 40% – clearly presenting an enormous challenge for the electric power industry in terms of global climate change. SGT deployment is a vital tool in addressing the challenges of climate change, ultimately and significantly reducing greenhouse gases [37].

Facilitation of Plug-In Hybrid Electric Vehicles (PHEVs): A SGT will also facilitate the market adoption and interconnection of (PHEVs), which can be plugged into electrical outlets for recharging [26].

This functionality extends the range of vehicle operation on the electric motor, compared to modern hybrids, and reduces the dependence on fuel. From a societal perspective, the deployment of PHEVs will lead to CO_2 reductions [29], [15]. The strong dependence on foreign sources oil addiction, together with the growing awareness of global warming impacts that CO_2 emissions produce, is the critical driver for the development of a new transportation system. This will lead to a reduction in the need for alternative oil sources of energy [35].

Generation Alternatives: With the development of renewable energy coming from such resources as the Sun and wind, the number of distributed generations increased dramatically. With the distributed generation and energy storage system being connected to the power grid, power network structure becomes more complicated. The capability to accommodate a wide variety of generation options is essential to enable the full promise of a modern grid. The generation will increasingly include renewable and distributed generation, alongside energy storage and other "non-traditional" sources [19].

IX. Research method

This research employed a qualitative study methodology. The questionnaire survey was targeted at 120 participants using the random sampling technique, which ensures bias is not introduced. The questionnaire followed the structured approach with a predetermined set of questions design to capture data from respondents. The respondents, who are experts from the Ghana energy sector, were asked to rank drivers, relating to the smart grid technology piloted by BPL Global Ltd. (BPLG). The drivers are classified as operational, market, security, regulatory and environmental. The operational drivers include new infrastructure, simplicity, reduced transportation requirements through automated meter reading, facilitate enhanced demand response and load control, accelerated innovation in devices through open standards, enhanced customer service and quality of supply, and improve operational efficiency. Market drivers include high demand, consumers and advanced electricity service, and solution provider's affordability, application for the benefit of both customers and utilities. The energy security drivers consist of security and resilient, safe and increased reliability. The environment involves generation alternatives, emission reduction and facilitation of plug-in hybrid electric vehicles (PHEVs), transmission and distribution, and generation alternatives. A total of 80 fully answered question Energy-saving certificates, emission trading schemes, energy and emissions taxes, information dissemination, environmental policies and increased environmental consciousness.

naires were computed.

The research focused on participants who are working with the energy sector such as ECG, VRA and GRIDCO, as such participant are well-placed to respond to the being investigated. Potential participants were identified through an online search of the companies' website (i.e. ECG, VRA and GRIDCO).

X. RESULTS & DISCUSSION

The investigation result reveals that the majority of the respondents believe that new infrastructure and generation alternatives are the key drivers. The operational drivers were closely followed by high levels of reduced transportation, simplicity, intelligent, enhanced demand, response and load control.

The research reveals that the lowest-ranked operational drivers are accelerated innovation, enhanced customer service and quality of supply. According to [25], technology transfer is not just a process of capital equipment supply from one firm to another.

The current market structure faces several challenges, which will only become more stringent shortly. Residential electric energy consumption continuously increases due to rural electrification. Regardless of these challenges, the power system needs to operate economically and reliably. [38]. Consumers around the globe need a continuous and reliable and cost-effectively energy supply. Global consumers' general concerns Smart grid is envisioned to address these concerns in a sophisticated and dynamic way entirely [14].

Market-related driving forces are subject to the need for a firm to stay competitive in a market by decreasing energy use. Some of the commonly cited market-related driving forces are "cost reductions resulting from lower energy use" and "threat of rising energy prices". Both factors are associated with the need for a firm to increase dividends or secure its future profits by reducing energy use [39].

The majority of respondents indicated that affordability is one of the key market drivers for smart grid implementation, followed by utilities and high demand. The lowest rank includes consumers, advanced electricity service.

There is a need for greater flexibility and increased cross-border trading, and the need to ensure economic development, transparent investment remuneration system and transmission and distribution costs as low as possible. The findings of this research agree with other analysis discussed in the literature about market drivers [40]. The success of such initiatives does, however, rely on the Ghana government engagement with various stakeholders, investment subsidies, tax exemptions, and many more are active promoters of industrial energy efficiency implementation. These instruments focus on capacity building in energy service markets and promoting efficient energy.

According to the respondents, market-related driving forces like "affordability and utilities are the essential promoters for implementing energy efficiency measures or technologies.

The Ghana Governments legislature has to prepare new legislation to take into account innovative SGT, the evolution of smart grid, creation and high-quality security of supply in Ghana's regulation and standardisation covering grid issues are either not harmonised or lacking in national laws and codes. The various stakeholders and all the energy production technology sectors should work together in conceiving a future Ghana energy sector that takes into account the needs of all its users. As soon as current regulations governing the electricity systems [41].

The most crucial opinion revealed by the present research was the ability to carry out a wide-scale deployment.

The environmental issues have moved to the forefront of the utility business with concerns regarding greenhouse gases and their impact on climate change [42]. Environmental awareness and interest was a prominent driver. This paper demonstrated that generic alternatives are a crucial main environmental driver follow by emission reduction and their role in the implementation. Other ecological drivers, such as no environmental compulsion emission reduction, ranked by the respondent as the second driver. The key drivers, which have affected the project deployment, were also noted by [38]. The survival and growth of a clean technology start-up must be built upon a competitive clean energy technology. The growing concern of the impacts of greenhouse gas emissions on global climate change has prompted a reassessment of the current approach to achieve a more environmentally sustainable energy supply for the future [43].

The reduction in fossil fuel reserves have caused the governments all around the world to implement Carbon Pollution Reduction Schemes, which have become an integral part of their energy policy framework [44].

The various component of energy security revealed that resilience of the power system is the critical drive, followed by security and increased reliability. Energy-efficient technologies have many advantages, including reducing climate change, improving sustainability in the power sector and increasing protection of power supply. The push to promote clean energy and reduce the nation's dependence on foreign oil calls for renewed attention.

Despite a large number of regulations in Ghana and other counties around the globe, regulatory drivers do not seem to play an important role as might be presumed when it comes to the implementation.

As part of efforts by the Ghanaian government to promote energy efficiency, there are policy instruments which indirectly encourage energy conservation in industrial firms. Additionally, some contextual factors in the form of massive energy subsidies, low energy taxes and lack of emission taxes are currently factors counteracting the improvements of industrial energy efficiency in Ghana. The lack of such a policy instrument in Ghana explains it being ranked as the lowest driving force. The success of such initiatives does, however, rely on national governments to properly engage with various stakeholders. Adequate policy support, together with awareness and technical support, would provide the impetus of adoption of clean energy-efficient technologies in the energy sector [22].

XI. Conclusion

This paper has examined the drivers behind increasing use of smart gird and offers propositions from the clean technology. This framework can make valuable contributions to the theoretical and practical elaborations, since it has been noted that the development and deployment stages are interrelated and share a drive for the pace of full diffusion of clean technology. Such a view requires paying particular attention to the key drivers.

The study presents a useful insight for future policies and government support towards smart industrial implementation in Ghana, and lays a bedrock for further studies.

Making it happen will allow Ghana's electricity grids to fulfil the expectations of society in the 21st century.

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