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Challenges, Opportunities and Profitability in Virtual Power Plant Business Models in Sub Saharan Africa - Botswana

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ABSTRACT

The growing awareness among the various communities on dramatic climate change in the recent years and impact of fossil fuels as a source of energy which is depleting fast, has got researcher thinking on alternate sources of energy with an aim for sustainable living for the livelihood of many countries. In this context, VPP turns out to be a promising solution as a sustainable future with renewables feeding the plant. VPP is congregation of distributed resources pooled together. Not only is this system efficient with updated digital technologies in the form of Smart solutions, but also capable of providing immense benefits to consumers/prosumers. Immense benefits in the form of sustainable renewable power as a source of income makes VPP attractive to consumers, who turn as prosumers and arguably become one of the most value creators in the energy market. The plethora of R and D in VPP grid adds value to energy business while maintaining and bringing down the ill effects of CO_2 emissions. This paper focuses on various aspects and business models, value propositions and the challenges in context to Sub Saharan African region - Botswana.

Keywords: Virtual Power Plant, Demand Response, Demand Side Management, Time of Use, Critical Peak Pricing
JEL Classifications: A12, M29

1. INTRODUCTION

As of 2016, over 5 million people across the globe has been living without electricity and this poses a major challenge to many developing nations. The grid infrastructure across many countries still operate in the same manner and not much has changed in its outlook. The same holds good for the generation part of the energy. One of the primary reason for the above is the inability of the Governments to focus on advanced technologies. The traditional electric grid continues to face multitude of challenges in the form of infrastructures, which is outdated and unfit thereby increasing the demand, network congestion issues due to inability of the grid to react to challenges on time, imbalances in the form of blackouts that prove to be costly for the utility companies due to communication challenges, the demand of the consumers to understand energy usage to make optimal usage and financial decisions, which is currently lacking, compatibility of the traditional grid to accommodate new emerging technologies in the form of renewable energy, which would otherwise increase efficiency and sustainability (Fangxing et al., 2010; Clement and Kevin, n.d.).

Many Governments have understood the problem and are now focusing to develop and incorporate advance technologies. One solution to this growing problem is in the form DER's and Smart Grids. These grid advances may accelerate the nations and regional electrification process and time frames thereby not only improving the delivery, minimizing costs, environmental impacts and also sustainable livelihood of the nation's population. This will envision the grid advances and enable to leapfrog elements of traditional power systems (Morgan et al., 2013). Considering the factors of growth in population, India and China being the leaders, it is crucial for the Governments to focus on Energy delivery and Energy Economy and to increase the livelihood of its population. According to WHO, Global Health Observatory (WHO, Global Health Observatory), "Earth's population has become abundant but the amount of world inhabitants living in cities has not surpassed people living by the country side until recent years." Therefore, the demand for energy is expected to grow significantly and considering the limited resources, it becomes a major bottle neck on the fossil resources and depleting natural resources. It is therefore essential to tap the renewable and alternative energy resources to lower the impact on the planet (Jesús et al., 2014).

IEA estimates that to achieve the target of providing electricity to everyone by 2030 will require additional power sector investment of USD 33 billion per annum on average for Sub Saharan Africa alone (UNEP, ILO, IOE, and ITUC, 2008). Efficiency, demand side management (DSM), optimal generation, improved grid transmission is essential and critical to achieving this goal and to minimize the volume of investments needed. Bazilian et al. proposed that the "current and emerging smart grid concepts, systems make an important contribution to improving equitable and just access to electricity services in Sub Saharan Africa" (Bazilian et al., 2010; Morgan et al. 2013; Fatih, 2010).

The recent trends in adapting to change in the energy market to employ smaller generation units is aiding cogeneration of locally distributed electricity and heat. Many countries offer incentives that boost renewable and distributed energy with a primary objective of increasing energy efficiency and energy resource. While the objective was to feed in maximum active power consumers in the past, but in the near future, with active participation of distributed energy units, supplying energy will increase. The fundamental idea of the designing the Renewable distribution energy networks were designed predominantly for passive operation. The focus was mainly to distribute electricity, from the transmission level down to the consumer with unidirectional power flow, while the future, will call for the distribution system to be more actively controlled with fully utilized network and distributed energy resource and renewable energy units more efficiently. In order to better understand the impact on the distributed generation (DG), the focus should be on the virtual power plants (VPP) from a technological and economic perspective. While VPP acts as pools of autonomous generation units for producing both heat and electricity, the solar cells can only be provided to the consumers locally. In principle, VPP are suited for long-distance transfer (Markus et al., 2012).

One way to achieve this goal is going "SMART." As indicated by Gellings in his book, smart means an "intelligent use of Communications, Computational ability, efficiency, control with technology to enhance the overall functionality of the delivery system" (Clark, 2009). In simple terms the new model VPP, will offer enormous benefits and the hosts will enjoy reap the benefits in the form of efficient delivery and control system. This will enable delivery of additional energy to the power feeders, thus increasing the amount of utilized energy and at the same time consume the energy in a more efficient way and at the same time return the unutilized energy back to the grid. This awareness will forth come due to the cost benefits, who will now be both consumers and prosumers (Jesús et al., 2014). The transition from the traditional energy approach to a distributed network approach in the form of VPP will enhance sustainability and efficiency and will result in dynamic changes to energy portfolio in the long run.

1.1. Smart Grids (SG)

Smart grid is a giant leap and it bridges the gap between the traditional technology as it harnesses communication and information technology to enhance the grid reliability, integration of various renewable energy sources, demand response, storage and transportation. It also allows and enhances competition among the service providers, enabling greater use of intermittent power resources. It helps in establishing the wide area automation and monitoring capabilities needed for bulk transmission over longer distances and distributed power generation. It empowers efficient outage management, streamlines back office operations thus aiding the use of market forces to drive retail demand response and energy conservation. "Smart Grid will be a driving force and act as a backbone infrastructure to enable new business models like smart city, electric vehicles, smart communities apart from more resilient and efficient energy system and tariff structures." With its dynamic approach, smart grid technology undermines factors like policies, regulation, and efficiency of market thereby restricting the global power scenario aids in costs and benefits and services that normalizes the marketing strategy. The concerns like secure communication, ethical data exchange, standard protocols, advance database management and efficient architecture is also taken care of and addressed. "As is the benefits associated with this technology, it also comes with burgeoning issues in both technical and non-technical aspects. Researchers and power engineers are addressing to eliminate these key issues for the proper and sound implementation of the technology across a large network (Balijepalli and Khaparde, 2011).

1.2. VPP

The VPP (Figure 1) model takes it cue from the internet model, where the active network is taken to the global level but distributes the control around the system. "As its name implies, a VPP doesn't exist in the concrete-and-turbine sense. Rather, it uses the smart-grid infrastructure to tie together small, disparate energy resources as if they were a single generator. Just about any energy source can be linked up and energy that's used can also contribute to a virtual power not (VPN) plant's capacity" (Kumagai, 2012). VPPs can be termed as manifestation of trans-active energy implementing new technologies as demand response, solar photovoltaic systems, advanced batteries, electric vehicles thereby transforming consumers actively to participants in delivering services. VPP is a system that relies upon software and smart grids to remotely and automatically dispatch and optimize DER. In short emerging energy cloud allows consumers to actively participate in the generation and distribution of electricity in strategic ways to achieve business models that benefit consumers, producers, and distributors of energy. Figure 2 provides an overview of various functions in a virtual power plant.

1.3. Demand Response (DR)

Demand response was first employed in US during early 1970's (Brett and Lauren, 2016) It is a set of policies that is targeted and aimed at lowering energy demand at peak hours. Demand response forms a critical part in power stations. Over the past decade, the DR programs have become more complex and scalable and has become the crucial part of energy systems due to its operational reliability. With the focus on DER's, it is essential that a centralized management and control be exercised for better management on the market side of the energy market (Jesús et al., 2014). According to Navigant research it is estimated that the global DRMS spending is expected to grow to 232 million in 2025 (Brett and Lauren, 2016) due to DER's. DR's are closely linked and dependent on changes made by consumers, encouragement on monetary feedback to induce lower energy consumption especially

Figure 1: Typical virtual power plant

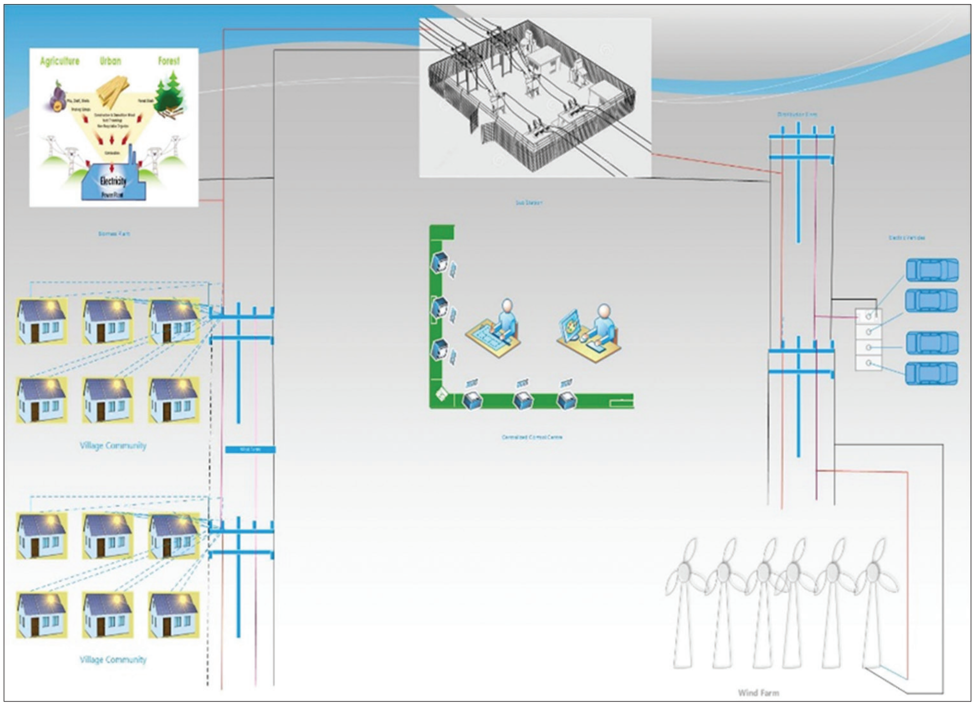
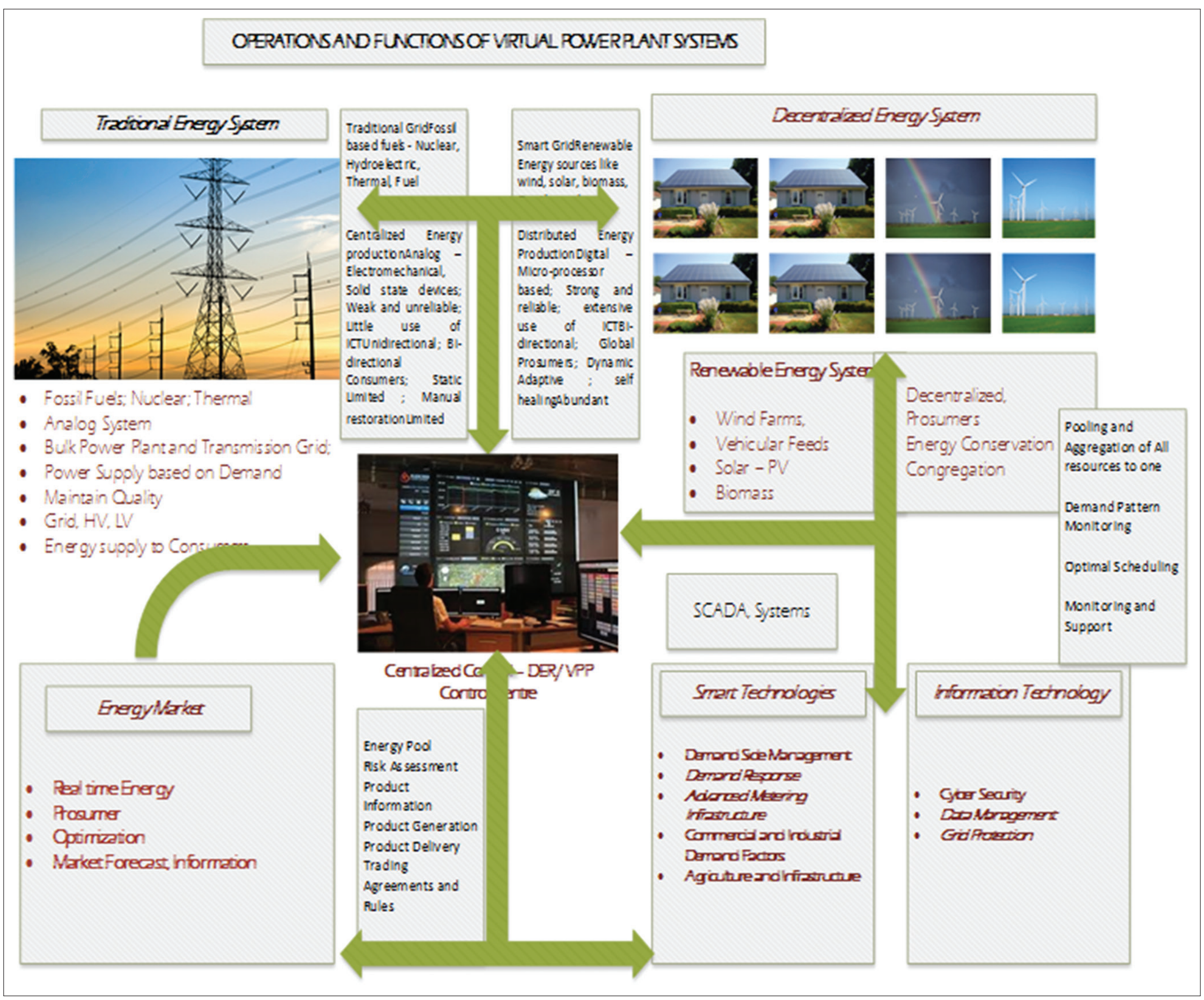


Figure 2: Operations and functions of VP



during high wholesale market prices, will assist the system when reliability is compromised (Jesús et al., 2014).

1.4. DSM

DSM was primarily used for providing cost effective energy with a focus on rationalizing and lowering differences in energy usage during peak hours. It is a complicated set of programs used for planning, implementing and monitoring activities of electric utilities (Independent Statistics and Analysis, n.d.). It helps in deferring the need for new sources of power in generating facilities, power purchases, transmission and distribution. DSM used to help shift loads during peak hours to non peak hours. It also helps in understanding energy pattern used by a specific consumer and enhance customer service. DSM is a long term strategy to evaluate and develop more efficient methods to save and plan energy (Wei-Yu et al., 2012).

1.5. Consumer/Prosumer

In traditional electricity distribution systems, the end user is the consumer, who consumes electricity generated. However, In a VPP model, the consumer not only consumes electricity generated but inturn becomes prosumer, in short he feeds the grid back with the unconsumed electricity generated as depicted in Figure 1.

Energy generated in a power plant normally passes through various stages, the generated energy is transmitted through a grid infrastructure. Typically the energy generated is stepped up in kilovolts, then stepped down at the distribution layer and supplied to the consumer as in Figure 3 (power distribution stages) and Figure 4 (power supply stages). In a VPP the process continues and the consumer who now is a prosumer feeds the power back into the grid. Though there is no fundamental change in the services, additional role in the form of generation will be added to the element in a VPP model. The obvious being the DG of energy through DERs, which will be advantage to the consumer/prosumer and can be quantified in economic terms. It is not essential that the consumer/prosumer, who now forms the core, will need to feed the grid back, but could be self-sustainable influenced by the environment in which he/she operates thus leading to an energy efficient market. However, this drives the necessity for efficient market based operation and control, necessitating a centralized form of control due to large population of autonomous prosumer to obtain coordinated participant behavior in an optimized environment and global performance (Jesús et al., 2014).

The basic power grid structure in Sub-Saharan Africa, especially in Botswana, has remained the same and not changed substantially for more than 30-40 years, thus posing challenges to the implementation of Smart technologies. Therefore it is critical that the grid infrastructure be upgraded or enhanced, rather than replaced to cater to the new technology. This will necessitate addition of new hard wares like AMI, RES, DG and Network infrastructures. Necessary software technologies needs to be incorporated as a part of grid upgrade. This envisioned grid will result in new services and generate new markets and create more jobs, which the country is now starved of, with over 41-49% unemployment. This model will bring in new business opportunities encouraging the use of technology driven economy with participation from small and medium enterprises. A brief comparison between traditional electric grid and a smart grid is tabulated in Table 1.

Figure 3: Power distribution stages

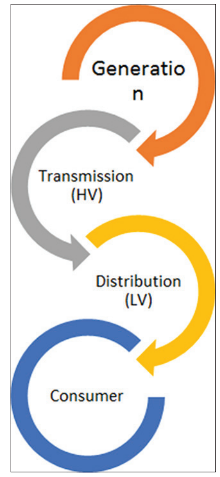
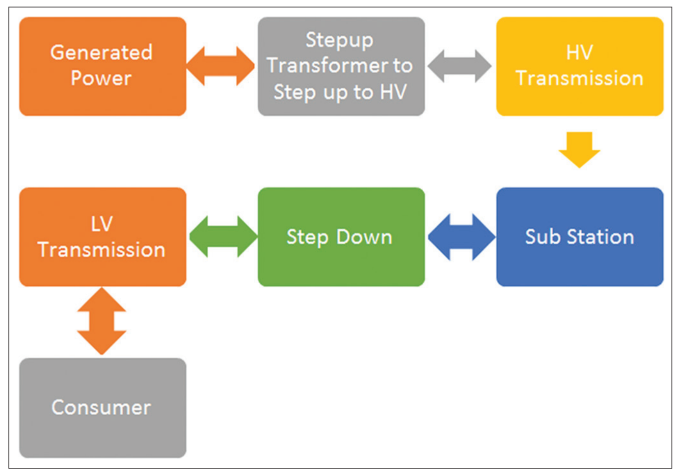


Figure 4: Stages of power supply



The main aim of this paper is to apply business model concept in VPP. This paper highlights emerging business opportunities in VPP along with SWOT analysis on the assumption that there will be active participation from prosumers. The main contributions of this paper are:

i. Review on most prominent business models for prosumers in VPP.
ii. Role of prosumers in VPP and their value in electricity chain.
iii. Value propositions with respect to Botswana Energy prosumer business model and their impact is formulated.

The paper is organized as follows, an introductory section on smart grid technologies and VPP. The next section deals with related works in the area, section 3 highlights the challenges in VPP, section 4 describes the business model and outcomes, section 5 describes prosumer values and section 6 concludes the research paper and an approach to future works.

2. RELATED WORKS

Many factors influence the energy market. Market demand and response, energy infrastructure, government policies, physical

Table 1: Comparison between traditional and smart grid (Rahat et al., n.d; Jesús et al., 2014)

Component	Traditional grid	Smart Grid
Energy generation	Fossil based fuels - nuclear, hydroelectric, thermal, fuel centralized energy production	Renewable energy sources like wind, solar, biomass, geothermal Distributed energy production
Technology	Analog - electromechanical, solid state devices; weak and unreliable; little use of ICT	Digital - micro-processor based; strong and reliable; extensive use of ICT
Communication	Unidirectional; bi-directional	Bi-directional; global
Business models	Consumers; static	Prosumers; dynamic
Protection	Limited; manual restoration	Adaptive; self healing
Data	Limited	Abundant

distance etc., play a vital role in any business model. Market demand and response in the energy market is predominant factors in influencing the energy production, consumer consumption/behavior and is normally noticed in open energy market. In the sub Saharan countries of Botswana, South Africa, Zimbabwe, Swaziland, Lesotho etc., the energy is exchanged in a South African Power Pool in a bid market. In US and other European countries the market is driven by development and commercialization of market value creation like jobs, system efficiency and environmental incentive programs (Ma et al., 2016; SAIC, 2011). It is essential that the Sub-Saharan Africa unites different energy infrastructure across nations to establish good interconnectivity standards of renewable energy sources for enhanced flexibility, information flow, improved system, control, DSM, demand response, which are critical for development and design of new business models (Ruud et al., n.d; Ma et al., 2016).

The critical energy infrastructure in Sub Saharan Africa is weak and unreliable in terms of T&D as compared to South Africa. Bello et al. (Mobolaji et al., 2013) in his case study on South Africa indicates that the electricity generated is not sufficient to meet the increasing demand. In a comparative scenario with South Africa, the energy generated in Botswana is not enough to meet the growing demand and fails to meet the peak demand. About 46% of the generated electricity is lost in transmission across rural Africa (Ma et al., 2016). These losses alone warrants for VPP model. Therefore it is essential that the losses in T and D be minimized. Technically, a loss in the T and D has to be compensated by increase in electricity generation. Rural areas in Botswana lack electricity and cost of distributing energy to these remote and rural areas is cumbersome and expensive, causing social inequality.

One major challenge in a VPP grid infrastructure is flexibility and unreliability, given the type of architecture which is complex, paving way for adding or removing members. The reason attributed to this is the willingness of the members to contribute the generated electricity, since a member may wish to contribute any amount of power generated, thus making the member unreliable. This could result in unreliable energy supply to the buyers or the market bidders in long term. Rathnayaka et al. (2014) in his goal oriented model, explains and highlights this scenario as prosumers are not goal oriented in VPP, but interconnected members via technical infrastructure. These minor challenges could affect long term relationships in a VPP due to differing opinions, interests and preferences. The authors propose a model 'Goal oriented prosumer community groups' as a solution to overcome this problem through means of sustainable social aspects with regards to prosumer management. In their proposal to solve, the select prosumers of common interests and targets, solve it in four major steps of (1) obtaining segmented profiles, (2) negotiation process among partners involved, (3) introducing new prosumers during the process and finally ranking the members.

Da Silva et al. (2014) stress the importance of performing accurate forecasts for local energy communities as a whole, to offer service that could become business model for energy consumption forecasting. They insist that the local energy markets are more desirable model for generating electricity because of their software management control facilities, efficient resource allocation and dynamic pricing.

Karnouskos (Karnouskos, 2011) indicates the importance of how services will be used by prosumers to their advantage in the future. The author indicates, since the system is bi-directional information exchange between production centres and end users is dynamic, how timely energy monitoring and consumption habits aid in automated decision making, management of different subsystems and devices, energy brokering strongly related to energy trading in the energy market, real time analytics and value added services, community management services of common interests for a group of prosumers, energy application stores. The authors also highlight the importance of interoperability.

Kato et al. (2012) discusses decentralized electricity storage in smart grids. They indicate that excess energy produced by the consumer is a source for revenue and energy that could be harvested by the prosumer from the storage as and when required. This aims to optimize energy distribution significantly by completely being independent of the grid. These storage bank is referred to as clusters by the authors. In a cluster environment energy generated from each and every prosumer is networked similar to the IT network, called energy network, thus enabling inter cluster energy transfer thereby effectively utilizing the energy generated.

One of the most important components of the VPP infrastructure is AMI (McLaughlin et al., n.d). It replaces analog meters with computerized systems to report usage over digital communication interfaces. Since VPP component is more of digital interface technology, it is easy to ready the energy usage data involving prosumers and analyze the usage, manage etc. However, with AMI, it comes with its own risks. One critical associated risk is manipulating energy data and validate the viability of the attacks by penetration testing on commodity devices (McLaughlin et al., n.d). A constructive study in the machine to machine communications has been highlighted by Željko and Vanesa, 2014 in their near accurate study of AMI. The authors bring out various challenges at different layers in the AMI.

Theft is another major problem in a developing country like Botswana, it poses a great challenge. The reason being people have a little understanding or no insight of the grid and with higher poverty ratio, power theft is quite rampant. Added to this is also the most common theft of equipment itself, basically for copper poses a greater risk on business operations from a business perspective.

Many environmental factors influence Botswana. Botswana being a landlocked country is entirely depending on neighbouring nations South Africa and Namibia for imports. Apart of the logistics involved, the primary market for Botswana is the rural grid infrastructure. The rural grid conversion process to microgrids is an expensive affair considering the distances between the villages. This poses a challenge in the form of establishing a firm grid infrastructure. It is therefore essential that there be proper grid technologies be implemented while carrying out rural electrification with proper optimization technologies and grid independence to ensure resilient electric supply. This creates a market attractiveness for the public-private partnership and will encourage FDI in the energy sector and will also aid Botswana in long run of creating a grid independence to overcome reliability issues.

As Botswana is poised to invest in power sector hugely to meet the growing demand in the country. With transition from analogous to digital electricity, there are numerous infrastructure challenges associated with it. One of the key challenge is in communication. With communication comes security, data management etc., where there is a huge gap, as digital networks are more prone to cyber-attacks from software hackers with malicious content. The envisioned grid is potential target to the malicious hackers and well-motivated adversaries as studies and experiences in the IT and telecommunication system indicate. Thus security becomes the primary issue that needs to be addressed. Security concerns on invasion of privacy and personal consumption data arises with the new digital electricity infrastructure. Traffic management in VPP will rely on large scale simulation and multi route planning. This will create a huge influx of software demand and will allow to develop software functionality in virtualization. Virtualization of the power grid will create dependability problems compromising security. Thus integrity forms the core essentials of the VPP grid. Botswana at present has no specific cyber security policies or mandates. Sporadic cyber security attacks like the Stuxnet, Shamoon across the globe in various countries, have indicated that these attacks can cause significant damage and pose a risk to National Critical Infrastructure. Thus it is essential that there be no loop holes in security planning as part of designing the VPP grids, which otherwise can potentially leave gaping holes in the Botswana's power sector stability. "With the evolution of cyber threats/attacks over time, the motivation of the attackers also evolved significantly driven by financial gain - from organized crime with well-established market places for trading in malware and stolen credit card data to attacks that are designed to create mayhem and cripple the National" Critical Infrastructure (NCI) (Anand et al., 2013).

The grid can be subjected to physical attacks by a hacker or by using malicious software codes specifically targeting the control systems or systems resources to accomplish one's own tasks. One of the finest example is DDOS attacks. These forms of attacks causing disruption to the grid can be highly motivating to a few and dangerous. It is likely to send out wrong signals in the energy market. Due to high grid efficiency and connectivity, the grid will enable personal information collection at ease and with it comes a very crucial package "Customer Data." Any form of attack on this will be invasion on the "consumer privacy." Threats on bills example manipulating with billing information of particular or specific user, can have a major economical disturbance unless monitored carefully. Since power grids play a major role in nation defense systems, any form of attack on these grids can cause havoc. Any failure on the part of the stake holders to eliminate these threats will hinder the modernization of the existing power industry. The existing well protected IT infrastructure, which encompasses contemporary security technologies such as VPN's, Intrusion Detection Systems, public key infrastructure, anti-virus software, firewalls, etc. cannot be very effective by direct deployment on the smart grid unless some critical changes are effected into the system due to inherent differences prevalent in them. The North American Equipment Council (NREC) reported the effects of a slammer worm on the power utilities used over in North America. In a quoted example they claim: The worm migrated through a VPN connection to a company's corporate network until it finally reached the critical Supervisory Control and Data Acquisition (SCADA) network. It infected a server on the control-center LAN that was running MS-SQL. The worm traffic blocked SCADA traffic (Jing et al., 2012).

With the advent of VPP grids and their ability to generate huge data on consumer, about their usage and patterns in usage of electricity and other personally identifiable information PII security is paramount. This is infact another area that the security should be focused on. Cyber terrorism and Cyber security are two synonyms. With advancement in ICT technologies and extensive use of it in ICS in energy sector, it has its pro's and con's. Energy sector does an excellent job of managing risks facing their operations. This data in any wrong hands can be misused wreaking havoc. This information can be used against the very own consumer as his usage "can reveal whether a person is at home or away, or what kind of devices being used etc." This is in addition to the security attention that needs to be provided to the critical infrastructure. Anand et al. (2013) however, cyber security and terrorism remains opaque and stubborn to monitor, manage, measure. It is critical that the environment for this be analyzed.

3. BUSINESS CHALLENGES

There are numerous challenges in business scenario in the VPP grid due to the disparity among the studied models and introduced models (Jesús et al., 2014). Research from various angles indicate and narrow down to few common challenges.

Although DER's technology is present in many nations, yet manufacturers and vendors struggle to make it visible. The VPP has still a long way to go, relatively due to the low impact that it has made and often mistaken due to myths, rather than the technological systems behind it. Lack of interconnectivity among the manufacturers is also one of the attributes, as different manufacturers incorporate different systems in their smart technology systems, thereby making interaction in the public pool difficult. This leads to business models from a prosumer angle to be weak.

The majority of negative business examples are undermined by two fundamental challenges:

- High capital and operating costs
  Capital and operating costs take the major chunk of fixed costs linked to communications. Although, there is no significant growths in economic scale due to the hardware cost, it poses significant risks when integration and delivery tasks on the software. The fact that the smart technologies are expensive, when it comes to implementation on the budget side, which remains a bottleneck currently, there are other factors that needs to be taken into account especially on the associated risks on delivery. These risks can be mitigated by effectively by the policy makers and regulators by effectively implementing advanced digital technologies and seeking economies of scale.
- Regulatory framework
  Regulatory frame work poses a greater challenge in terms that the organizations tend to be conservative in calculating the benefits in what they can gather as cash benefits to the shareholders. It is considered that the operative losses are put on to the customer and as a result any drop in losses would impact the utility shareholder. Therefore regulators are required to place such policies and regulations in place that could benefit both the utility and consumer.

In addition to the above the environmental factors in the Sub Saharan region plays a significant role in the development of VPP.

4. BUSINESS MODELS

The business model concepts gained popularity recently, partly due to business interests and partly due to growth and globalization (Wendy, 2004). Definitions of what constitutes business models vary depending on the thought and has not established definition from a scientific literature (Amit and Zott, 2001; Amit et al., 2010; Wendy, 2004). Business model establishes governance of transactions, content, value creation by exploitation of business opportunities. Teece (2010) defines business model as tool that companies use to deliver value to customers for which customers pay thereby converting those payments into profit.

Many business models are in existence. Lee et al. (2010) discusses four models as smart energy savings, smart power trading/selling business, smart ICT convergence and smart city business. They discuss the use of integrated energy management. The business model can be characterized as shown in the Figure 5. The core parameters are customer relationships and segments, value channels and addition. Revenue streams are revenue assets, activities, partners etc. In the VPP business model shown in the Figure 5 is common and aligns with most business models and operations. Most business models have cyclic and inter-wound relationships in a conceptualized business model as indicated in the Figure 6. In this conceptualized business the key indicators are (1) prosumer benefits, (2) target market with value added services, (3) Infrastructure and asset management with advanced smart technologies, (4) generate customized revenue model for prosumers.

5. PROSUMER ROLES IN VPP

In a VPP, the consumer, who is also a prosumer is the focus and plays a vital role in the grid infrastructure. Smart grid users have always had a skeptical relationship between them, which can be attributed to the fact that they have not been participating actively (Daphne et al., 2013) This user-grid relationship is crucial to the performance and the success of the VPP model, especially in the management of the demand and supply in the plant. The paradigm shift from passive to active and from consumer to prosumer is essential for the efficient operation of the VPP. This societal and behavioral change strategies (Daphne et al., 2013) need to be

Figure 5: Business model concept for VPP

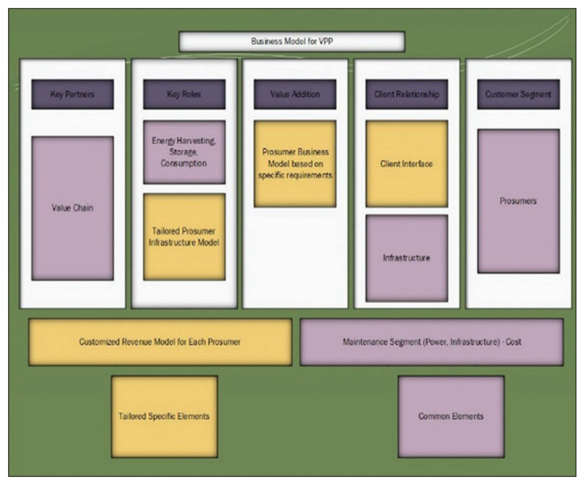


Figure 6: Conceptualized business model

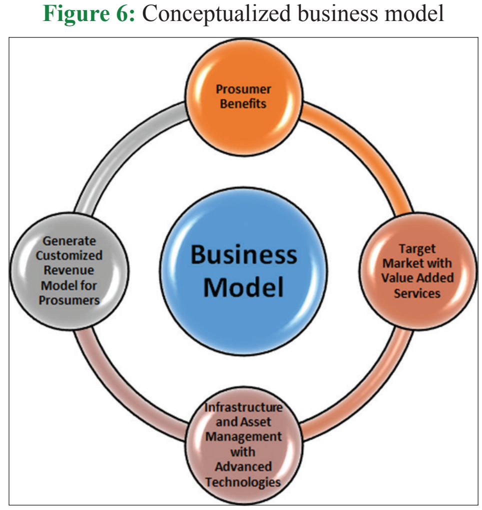
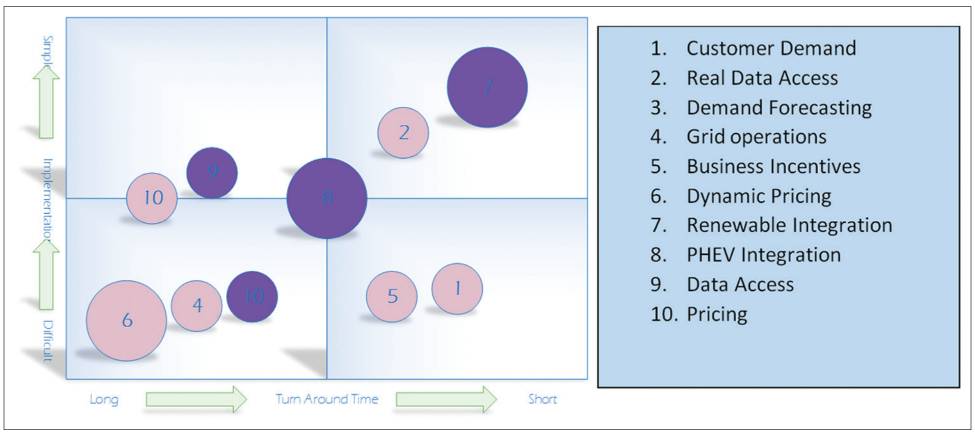


Table 2: Consumer behavior and impacts

Categories	Products/services	Tariff programs	Market component	Impact
VPP/DER's	Production			Electricity production awareness
	Timing			Willingness to turn on/off the production unit as and when required
	Pricing	Classic	Direct control	No impact
		Market based	Demand based bidding	Consumer awareness
			Demand response based on bid	Enhanced production and encourages prosumer to minimize usage in consumption to provide more to the market
			Capacity market	
	Dynamic pricing	Time of use (TOU)		Shifts in electricity usage resulting in lower consumption and vice versa
		Critical peak pricing (CPP)		
		Extreme day pricing (EDP)		
		Real time pricing (RTP)		

TOC: Time of use, CPP: Critical peak pricing, EDP: Extreme day pricing, RTP: Real time pricing

Figure 7: Gap analysis



applied successfully to change the users from passive consumer to active producer for efficient management of the VPP system. Considering the various challenges that are yet to be solved as a business model in VPP like device interface and interoperability, interconnectivity, third party interface and coexistence, it is essential that consumer behavior has a positive shift as he becomes the centre focus in the VPP grid infrastructure. In order to exercise the behavioral change, end users must adapt to and go through various phases like becoming aware of change and how to change, consolidating changes etc. Interventions will be essential to stimulate the consumer behavior as discussed in the Table 2.

Community based approaches have influence and profound advantages over the user behavior through social norms, peer learning, cooperation. It is therefore essential to have a proper governance at the community level for development of better solutions based on the localized impacts on issues. This will also enhance the transfer of technology in a profitable way (Gardner and Stern, 1996; Rogers, 2010; Wilson et al., 2007). One exemplary example is government funding to encourage solar rooftops as a means of providing, self-sustaining energy, encouraging and creating awareness among the people on climate change and to reduce dependency on fossil fuels. This cooperative initiatives have a profound impact on the management of renewable energy resources, at the same time encouraging the public in organizing their own energy provisioning methods with proper agreements and by financial gains. This will not only aid the consumer in their livelihood by means of financial returns, but also make the consumer proactive in terms of electricity production and return it back to the grid. Another key change is that since the consumer now behaves as a prosumer, it stimulates the services and product development in a positive manner, thereby providing easing communication between end users in the VPP Market. These interactions can be of many natures like providing and getting information about the energy usage and Services, energy consumption and Production, aid market with new innovations and thereby contributing to improvement in the VPP model smart systems. This transition will not only involve efficient energy usage but also efficient demand response management.

In a VPP the relationships among the operators and prosumers is bi-directional and forms an integral part of the energy market which is by nature Dynamic. Due to this dynamic nature of the energy market, clarity in terms of energy expectations and needs, preferences can be presumed with new set of roles, terms, technologies and energy demand with regards to their experience in electricity markets.

The market needs in Botswana is very different from the neighboring countries in Southern Africa. Due the environment challenges Botswana faces, it is important that the Government of Botswana encourages public-private partnerships in energy and draw FDI in

Table 3: Gaps correlated to action plan

Gaps	Reliability	Pricing	Resources	Energy efficiency
Customer demand			✓	✓
Real time data access		✓	✓	✓
Grid operations based on demand forecast	✓		✓	
Predictive grid operations	✓		✓	
Business incentives		✓	✓	✓
Pricing		✓		✓
Renewable integration	✓	✓	✓	✓
PHEV integration		✓	✓	✓
Device exchanges		✓	✓	✓
Data access beyond meter		✓	✓	✓

Figure 8: DR/DER

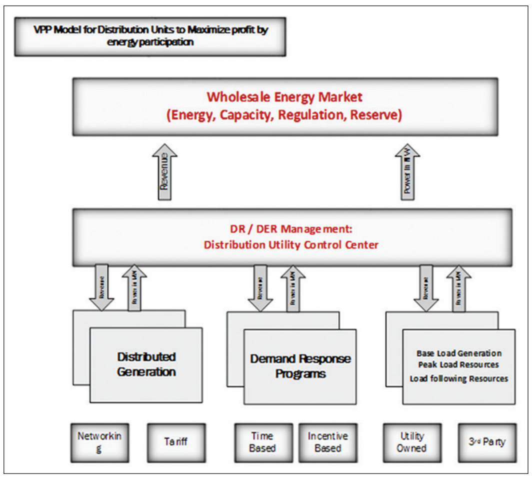
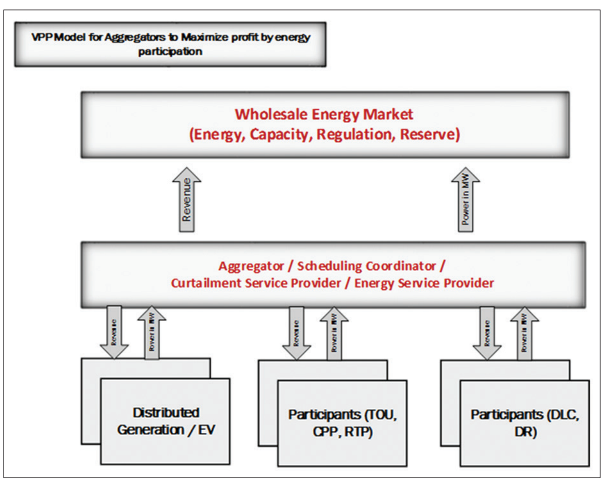


Figure 9: Aggregator



the energy market by providing incentives to investors and encourage public to switch to green technologies. Energy companies in Botswana will play a major role in the operation of VPP in the near future.

The capability gaps that challenges Botswana's energy market are Reliability, Energy efficiency, Resources and Pricing as detailed in the Table 3. In understanding capability gaps as in Table 3, the Government of Botswana needs to identify the degree of difficulty and turn around time to bridge the gap. With a view to bridge the gaps, the Figure 7 shows the relative impact of these gaps on energy plans for Botswana and could provide a helpful way to target these activities that provides the speediest return with least amount of efforts.

The utility corporations or energy companies will play a crucial role in the electricity market in this commercially viable VPP business model as shown in Figure 8. They coordinate power purchases and pool them together from individual micro generators to maximize revenue, meet demands by DR/DER programs. They also have the onus on coordinating participation in the energy market and operating reserve market which will ensure that the demand management is priority as per the available demand response programs, in addition to serving as energy conservators. This will also enhance their fundamental role in implementing of energy saving projects and serve as advisors for energy supply and risk management experts.

The functional responsibility of Aggregators/Retailers for purchasing electricity, metering and billing which had been their traditional role will evolve in contributing to research and development while still managing old roles. They will also play a role in creating innovative solutions through R and D, based on their experience and actively guide the prosumer in optimizing solutions, participation in the energy market etc., thus translating to active from being passive. The aggregator in the VPP has got multiple options and flexibility to bid market products like energy, reserve, regulation, capacity based on requirements, thus proving as a link in the chain for retail level demand side resources to wholesale market products. Thus he serves to manage multiple resources by aggregating DR and DER participants as shown in Figure 9.

Likewise the distributor operators, whose current role serves in distribution of electricity, safely with stability will evolve to an active network management operator in the power supply distribution network. Bompart et al. considers and analyses the interaction of prosumers with distributors to optimize resources generated in a distributed manner (Bompard and Bei, 2013). It is claimed that in using a distributed market, right signals are sent to the prosumers thereby making the prosumer more aligned to the distributors, inturn satisfying both the distributors and the stake holders (Jesús et al., 2014).

6. DISCUSSION AND CONCLUSION

In this paper, a thorough description of the main components of VPP grid has been put forth. The paper highlights differences in stake holder relations, market factors impacting the VPP. A comprehensive explanation on prosumer oriented business models have been highlighted and tackled. The paper goes on to explain how prosumers are the centre focus in a VPP environment, how their roles and decision making will help in energy market value chain.

The overview of VPP products and services portrayed in this research paper highlights the importance to involve consumers in VPP operation actively to aid them financially and technically. Consumers turned Prosumers are key to energy management. Prosumers are the key to the development of the VPP grid and are an integral part of the energy market value chain and are the greatest asset in the business model based on the services in which they take part. The growing demand for clean energy and market needs of organizational evaluation bring forth the necessity of introducing smart technologies and VPP in specific market of Botswana. The value proposition of each component of a VPP model generates new business opportunities and aids in the transformation of electricity market. Since Prosumers form an integral part, VPP model not only saves energy but energy costs to the consumers, and also acts as financial livelihood component, as surplus energy generated is distributed back into the grid or the energy pool. Management of assets such as PV arrays, Wind farms, transmission and distribution lines which has been a bottle neck for many developing nations can be efficiently and reliably addressed by VPP solutions. There are numerous work in pipe line of many nations, and several works expected to be performed in the near future. VPP models are scalable models that could be expanded. As long as VPP models are deployed to users advantage, the scope for expansion into new technologies is tremendous where there is opportunity for the consumer to take a centre stage and play an active role in the VPP. In addition to that synergies in VPP business models focus on aggregators and hence there is scope for expanding research into these areas.

Cyber security is a growing threat in VPP business model. The threats are real with countless actors attempting to gain some mileage into some of the best protected resources in the energy sectors. Research works carried out in relation to threats and cyber attacks, indicate energy sector to be second most targeted sector across the globe. Although this paper highlights a few of the security issues a detailed research is beyond the scope of this paper. There has been little or no research done in the area of VPP impacts and this area can be research extensively.

REFERENCES

Amit, R., Zott, C. (2001), Value creation in e-business strategic. Management Journal, 22, 493-520.

Amit, R., Zott, C., Massa, L. (2010), The Business Model: Theoretical Roots, Recent Developments, and Future Research. Pamplona, Spain: University of Navarra.

Anand, K., Krishnan, P., Devendra, K.P. (2013), Facing the Reality of Cyber Threats. In: The Power Sector. White Paper (Wipro).

Balijepalli, V., Khaparde, S. (2011), Smart and Sustainable Energy Systems for Developing Countries: An Indian Perspective. (IEEE, Ed.) IEEE Power and Energy Society General Meeting. p1-8.

Bazilian, M., Sagar, A., Detchon, R., Yumkella, K. (2010), More heat and light. Energy Policy, 38(10), 5409-5412.

Bompard, E.F., Bei, H. (2013), Market-based control in emerging distribution system operation. IEEE Transactions on Power Delivery, 28, 2373-2382.

Brett, F, Lauren, C. (2016), Demand Response Management Systems. Navigant Research, Research. USA: Navigant Research. Available from: http://www.navigantresearch.com.

Clark, G.W., editor. (2009), What is the smart grid? In: The Smart Grid: Enabling Energy Efficiency and Demand Response. Lilburn, GA, USA: The Fairmont Press, Inc.

Clement, Kevin. (n.d.), Smart Grid Technology. Available from: https://www.smartgridtech.wordpress.com/smart-grid. [Last retrieved on 2017 Dec 05].

da Silva, G.P., Ilic, D., Stamatis, S. (2014), The impact of smart grid prosumer grouping on forecasting accuracy and its benefits for local electricity market trading. IEEE Transaction Smart Grid, IEEE Journals and Magazines, 5(1), 402-410.

Daphne, G., Angèle, R., David, K. (2013), Empowering the end-user in smart grids: Recommendations for the design of products and services. Energy Policy, 61(1), 151-161.

Fangxing, F.L., Wei, Q., Hongbin, S., Hui, W., Jianhui, W., Yan, X., Zhao, X., Pei, Z. (2010), Smart transmission grid: Vision and framework. IEEE Transactions on Smart Grid, 1(2), 168-177.

Fatih, B. (2010), World Energy Outlook 2010. Paris: OECD/International Energy Agency.

Gardner, G.T., Stern, P.C. (1996), Environmental Problems and Human Behavior. Needham, MA, USA: Allyn & Bacon.

Independent Statistics and Analysis. (n.d.), (US Energy Information Administration). Available from: https://www.eia.gov/electricity/data/eia861/dsm. [Last retrieved on 2017 Dec 05].

Jesús, R.M., Margarita, M.N., José-Fernán, M., Waldo, P.A. (2014), Business Models in the Smart Grid: Challenges, Opportunities and Proposals for Prosumer Profitability. (Elsevier, Ed.) Energies Open Access, 6142-6171. DOI: 10.3390/en7096142.

Jing, L., Yang, X., Shuhui, L., Wei, L. (2012), Cyber Security and Privacy Issues in Smart Grids. IEEE Communications Surveys and Tutorials, 14,(4), 998-1010.

Karnouskos, S. (2011), Future smart grid prosumer services. In: IEEE, editor. Proceedings of the 2011 2nd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies (ISGT Europe). Manchester, UK: IEEE. p1-2.

Kato, S., Nishihara, H., Taniguchi, I., Fukui, M., Sakakibara, K. (2012), Analysis on battery storage utilization in decentralized solar energy networks based on a mathematical programming model. In: IEEE, editor. Proceedings of the 2012 Joint 6th International Conference on Soft Computing and Intelligent Systems (SCIS) and 13th International Symposium on Advanced Intelligent Systems (ISIS). Japan: Kobe. p651-656.

Kumagai, J. (2012), Virtual power plants, real power. IEEE Spectrum, 49(3), 13-14.

Lee, J., Dae-Kyo, J., Yoonkee, K., Young-Woo, L., Young-Myuong, K. (2010), Smart grid solutions, services, and business models focused on telco. In: IEEE, editor. IEEE/IFIP Network Operations and Management Symposium Workshops. Osaka, Japan. p323-326.

Ma, Z., Lundgaard, M., Jørgensen, B.N. (2016), Triple-layer smart grid business model-a comparison between Sub-Saharan Africa and Denmark. In: IEEE, editor. Innovative Smart Grid Technologies - Asia (ISGT-Asia. Melbourne, Australia: IEEE. p374-352.

Markus, F., Daniel, R., Andreas, K., Antje, D., Andreas, G.S., Peter, L., Hartmut, S., Christof, W. (2012), Impacts of distributed generation from virtual power plants. In: Proceedings of the 11th Annual International Sustainable Development Research Conference No. 76131. Helsinki. p12.

McLaughlin, S., Podkuiko, D., McDaniel, P. (n.d.), Energy Theft in the Advanced Metering Infrastructure. Pennsylvania: Systems and Internet Infrastructure Security Laboratory (SIIS).

Mobolaji, B., Riaan, S., Clinton, C.B., Innocent, E.D. (2013), Power planning for renewable energy grid integration-case study of South Africa. In: IEEE, editor. 2013 IEEE Power and Energy Society General Meeting. p1-5.

Morgan, B., Manuel, W., Deepak, D., David, E., Goran, S., Mark, H., Lawrence, J. (2013), Smart and just grids: Opportunities for Sub-Saharan Africa. Imperial College, Imperial College of Science, Technology and Medicine. London: Energy Futures Lab.

Rahat, H., Amanullah, M.T., Shawkat, A.B.M. (n.d.), Smart grids. In: Smart Grids: Opportunities, Developments and Trends. London: Springer. p23-44.

Rathnayaka, A.J.D., Potdar, V.M., Dillon, T., Hussain, O., Kuruppu, S. (2014), Goal oriented prosumer community groups for the smart grid. (IEEE, Ed.) IEEE Technology and Society Magazine, 33, 41-48.

Rogers, E. (2010), Diffusion of Innovations. New York, NY, USA: Simon and Schuster.

Ruud, K., Paul, K., Anderson, H. (n.d.), Smart Grids and Renewables: A Guide to Effective Deployments. Available from: http://www.irena.org/documentdownloads/publications/smart_grid.

SAIC. (2011), Smart Grid Around the World. Available from: https://www.eia.gov/analysis/studies/electricity/pdf/intl_sg.pdf. [Last retrieved on 2017 May 13].

Teece, D.J. (2010), Business models, business strategy and innovation. Long Range Plan, 43, 172-194.

UNEP, ILO, IOE, and ITUC. (2008), Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World. United Nations Environment Programme. Policy Options for Africa. United Nations. United Nations. Available from: http://www.unep.org/labour_environment/PDFs/Greenjobs/UNEP-Green-Jobs-Report.pdf.

Wei-Yu, C., Hongjian, S., Vincent, P. (2012), Demand-side energy storage system management in smart grid. In: IEEE, editor. Proceedings of the 2012 IEEE Third International Conference on Smart Grid Communications (SmartGridComm). Tainan, Taiwan: IEEE Explore. p73-78.

Wendy, L.C. (2004), Value Creation from E-Business Models: Issues and Perspectives. Burlington, Oxford, UK: Elesivier.

WHO, Global Health Observatory. (n.d.), Urban Population Growth. Available from: http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en. [Last retrieved on 2017 Dec 05].

Wilson, C., Dowlatabadi, H. (2007), Models of decision making and residential energy use. Annual Review of Environment and Resources, 32, 169-203.

Željko, P., Vanesa, Č. (2014), Advanced metering infrastructure in the context of smart grids. In: IEEE, editor. Proceedings of the 2014 IEEE International Energy Conference (ENERGYCON). Cavtat, Croatia: IEEE. p1509-1514.