SUSTAINABLE ENERGY ACCESS IN WEST AFRICA REGION: THE ROLE OF NATURAL GAS

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Abstract

West Africa region has enormous gas reserves of over 182 trillion cubic feet and its total energy consumption is estimated at 201 million tonnes of oil equivalent. At the GDP growth rate of 5.9% per annum and a 4.8% share of global population, the demand for energy is projected to increase nearly 80% by 2040. Natural gas fuel is identified to play a major role and the best partner with which renewable energy can build a sustainable energy future. The region has the lowest access rate to quality energy globally. Despite the strides in some energy infrastructural development, the region is yet to harness the opportunities in natural gas utilization as a sustainable source of energy with a larger percentage of the population still suffering from poor access to modern forms of energy despite the huge potentials for sustainable energy growth. There is therefore the need to explore the production potentials of natural gas in the region, its share of the primary energy consumption, the strategic location of the major reserve holder – Nigeria with respect to other states in the West Africa region as well as surmount the potential challenges in creating a regional and functional gas market. To understand the role of natural gas in achieving sustainable energy access in the region, we applied the discrete choice method of primary energy supply, demand and pricing in the region.

Category: The geopolitics of oil and natural gas
Keywords: natural gas, energy security in West Africa, functional gas market, West Africa natural gas potentials, poverty and sustainable energy

Introduction

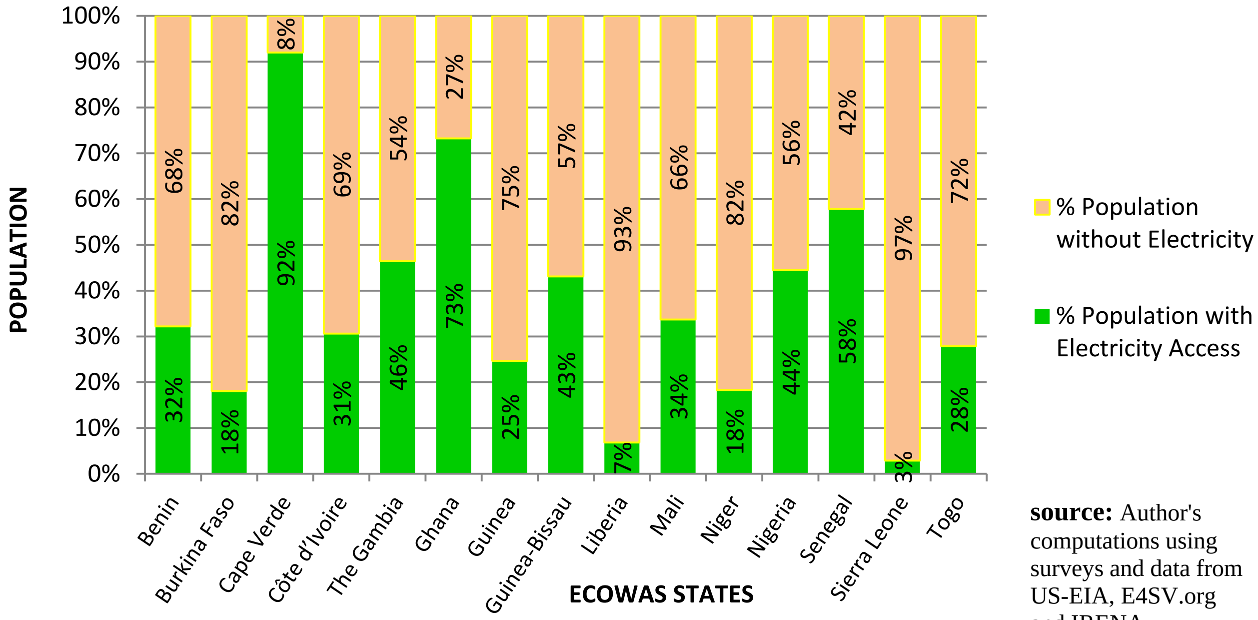
West Africa region ranks among the regions with lowest access rate to quality energy globally. The region boosts a teeming population of about 350 million people (UN, 2015) and abundant energy resources, and it is considered that the key to unlocking the development and growth index of the region would require both state and regional effort in solving its energy underdevelopment. Luckily the West Africa region has shared common economic interests in cultural and geopolitical ties that can be promoted in the ECOWAS (Economic Community of West African States) platform. The availability of energy resources coupled with the means to produce, distribute and consume as efficiently as possible has been the yardstick for development and growth of civilizations. In addition, energy plays a vital role in the improvement of the overall standard of living of the populace. This is especially a big concern for a region that has abundant energy resources – renewables, low carbon fossil-natural gas and other fossils-oil and coal. The West Africa energy situation is therefore one that if considerable and targeted investment is not embarked on, energy poverty with the attendant economic and social consequences will continue to be a challenge in the region for a long time. This is evident in the electricity access rates in the region (figure 1) which is as low as 3 to 10 percent in Sierra Leone and Liberia to about 45% access in Nigeria that has more than 50% of the entire West Africa population. Natural gas fuel which is considered abundant in the region has been identified as a cleaner and market ready alternative to oil and coal, capable of facilitating the systemic changes that will underpin the development of a more-energy-efficient and renewable energy-based economy (Flavin & Kitasei, 2010). Among the fossil fuels, natural gas is the fastest growing (1.8% p.a.) with an increasing share of primary energy consumption as compared to oil (0.9% p.a.) which is declining in its share globally (BP, 2016). This paper examines the economic importance that natural gas will play in meeting sustainable energy access in West Africa. It equally explores the prospects for integration and transition to sustainable energy and renewable energy mix aimed toward a clean energy future as recommended by the clean development mechanism (CDM). Recoverable natural gas reserves in the region mostly found in Nigeria are estimated at over 182 trillion cubic feet (tcf) while total production currently stands at approximately 3,003 billion cubic feet per annum (DPR, 2015). Nigeria contributing over 50% of the West Africa population is very strategic in both location (see figure 2) and in numbers towards the realization of the sustainable energy sufficiency of the West Africa region.

The paper is organised as follow: After the introduction, the second section explored the energy supply, access and use within the West Africa region. Section three addresses the West Africa energy use projections to 2040 to enable prediction of energy gaps. In section four the prospects for natural gas within the region as well as the potential challenges in creating a functional gas market were explored and discussed. Recommendations have been advanced in section five that would influence policy directions toward energy security and a low-carbon future with the hope to bridging the gap between poverty and sustainable access to energy within the region. We conclude in the final section that West Africa countries can leverage on natural gas resource found in the region for adequate access to sustainable energy while transiting to a clean energy future as recommended by the clean development mechanism.

West Africa Energy Supply, Access and Use

West African region is blessed with numerous energy resources that are considered large enough to bring about a sustainable energy future in and around the region. The estimation of the Sub-Saharan Africa energy resources, West Africa inclusive (IEA-AEO, 2014) indicate very large quantities of both fossil (figure 3) and a range of high quality renewable energy resources such as hydro, solar, wind and geothermal with significant portions not yet developed especially the non-hydro renewables. The Sub-Saharan Africa energy resources are estimated to sufficiently meet regional needs far into the future. However the West African region holds proved reserves of 38 billion barrels of oil which accounts for 2.3% of world's total oil reserves and over 58% of sub-Saharan Africa. It is evident in Figure 4 that over 90% of the West-African oil reserves are resident in Nigeria.

Sub-Saharan Africa (West Africa inclusive) accounted for more than 55% of new oil discoveries (about 14 billion barrels of oil equivalent) and large gas discoveries (especially in Mozambique) out of the total world new oil and gas discoveries in five years between 2009 and 2013, as depicted in figure 5.



source: Author's computations using surveys and data from US-EIA, E4SV.org and IRENA

Figure 1: West Africa Countries Electricity Access Rates

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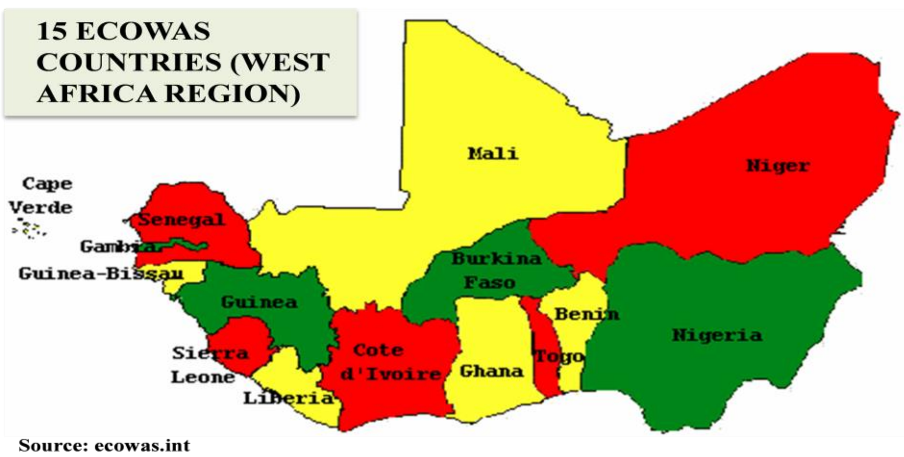

Figure 2: West African Countries forming ECOWAS 15

A number of the West African countries with little or no discoveries presently are increasingly witnessing success rate in oil and gas exploration. These include Ghana, Liberia, Sierra Leone and Cote d'Ivoire (IEA-AEO, 2014 page 50**)**.

The natural gas resources and reserves of the West Africa region are estimated at over 182 trillion cubic feet (tcf) of gas with ultimate recoverable reserves at over 374 tcf as shown in figure 6. Nigeria which is the largest in population size is endowed with the 9th largest proven natural gas reserves in the world (US EIA, 2016 page 59) and gas flared (from produced gas) alone is estimated to be equivalent to the total annual power generation in Sub-Saharan Africa (Okafor & Anichie, 2016; Kelly, 2007). With a 4.8% of global population and GDP growth rate of 5.9%, the total primary energy consumption in the region has been estimated at 195 million tonnes of oil equivalent (Mtoe) or 2273 terawatt-hour (TWh) at 2014 estimates (World Bank, 2017; US EIA, 2016).

The total energy production of approximately 312 Mtoe (or 3,631TWh equivalent) in 2014 is dominated by traditional biomass, biofuels/waste contributing about 48%, with 39% crude oil and 13% for gas, coal and renewable energy sources as shown in figure 7. Compared to the energy use statistics from table 1a and 1b, it clearly show a big gap in the energy mix between energy produced and energy used, which is the panacea for the energy poverty experienced in the region. This also coupled with lack of adequate regional energy carrier facilities – such as gas pipelines, electricity grid and solid regional policy and regulatory framework. More than 195 million people representing about 59% of the West African population have no adequate access to electricity (figure 1) and a good proportion mostly in the rural areas utilizes biofuels (firewood) for heating and cooking in an inefficient form posing health hazards to mostly the women and children population. Even in the urban areas, charcoal (biofuel) and kerosene are used as basic fuel for cooking and heating more than the use of liquefied petroleum gas (LPG). Similarly, the lesser population that have access to modern energy in form of electricity, transportation, cooking and heating face high prices and a supply that is both insufficient, erratic and unreliable, which explains the gross energy underdevelopment of the region.

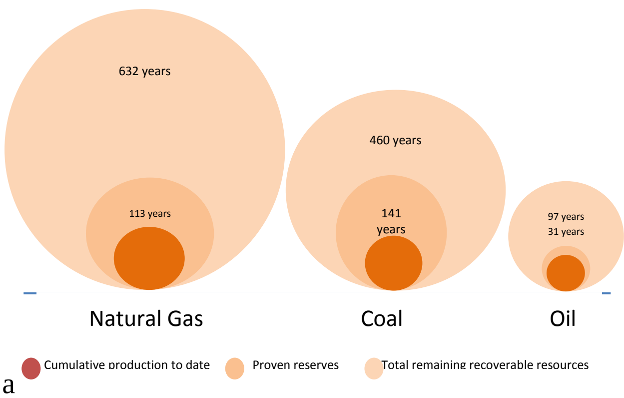

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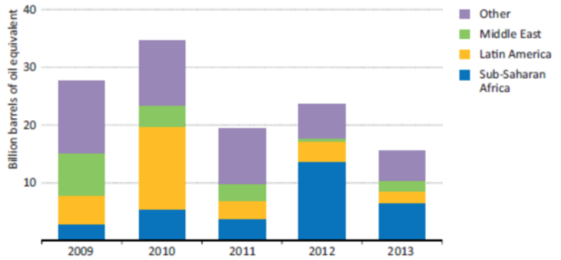
Figure 3: Sub-Saharan natural gas, coal and oil resources, 2013 estimates (source: IEA-AEO, 2014)



Sources: **IEA-AEO, 2014** page 49

Figure 5: World New Oil and Gas discoveries (2009 – 2013)

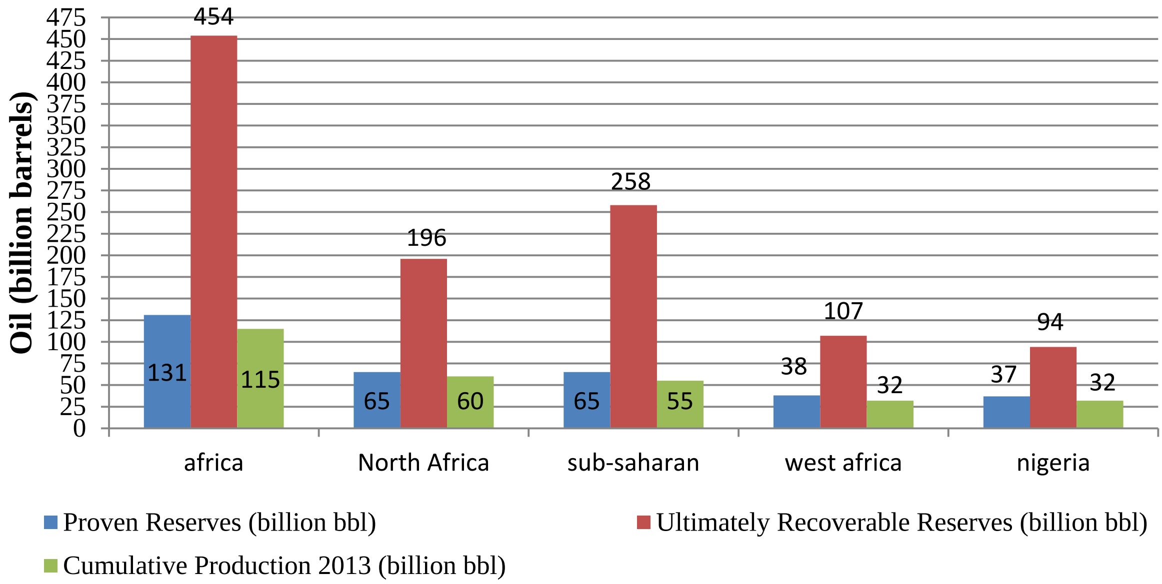


Figure 4: Africa Oil Resources and Reserves (IEA-AEO, 2014 page 52)

West Africa countries are endowed with range of renewable energy resources that are well spread and which according to IEA statistics for Africa (IEA-AEO, 2014) are capable of meeting in excess the domestic demand for a long time. Renewable energy sources in the region range from Hydro (including large and small hydro), biomass/bioenergy, solar and wind energy resources. Their capacity to provide sustainable energy in the region has been estimated at over **153** Mtoe which is considered enough to achieve grid parity in the region's electricity generation which in 2014 was 60.8 TWh (5.2 Mtoe) (IEA2014, EU-ICD, WORLDBANK, 2017; CIA, 2017). The IEA projections (IEA-AEO, 2014**)** for up to 2040, estimates that over 40% of the total primary energy demand (TPED) will be derived from the region's renewable energy resources as shown in figure 8.
As can be seen from table 2 below, the identified renewable energy resources of the West Africa region which is evenly spread creates a very fertile ground to underpin the framework for advancing the clean energy future of the region in accordance to the clean development mechanism. Noteworthy in this direction is the West Africa Power Pool (WAPP) which was created by the ECOWAS heads of state and

government to promote reliable and efficient power supply in the West Africa sub-region. Using about 58 percent utilization efficiency, the renewable resources potential of the region are capable of generating up to 153.5 Mtoe (1,785 TWh) of energy which is almost at par with the current overall energy demand in the region. However the efficient distribution of the low-carbon resources (renewable energies and gas) for a sustainable energy future within the region is not without challenges and bottlenecks.

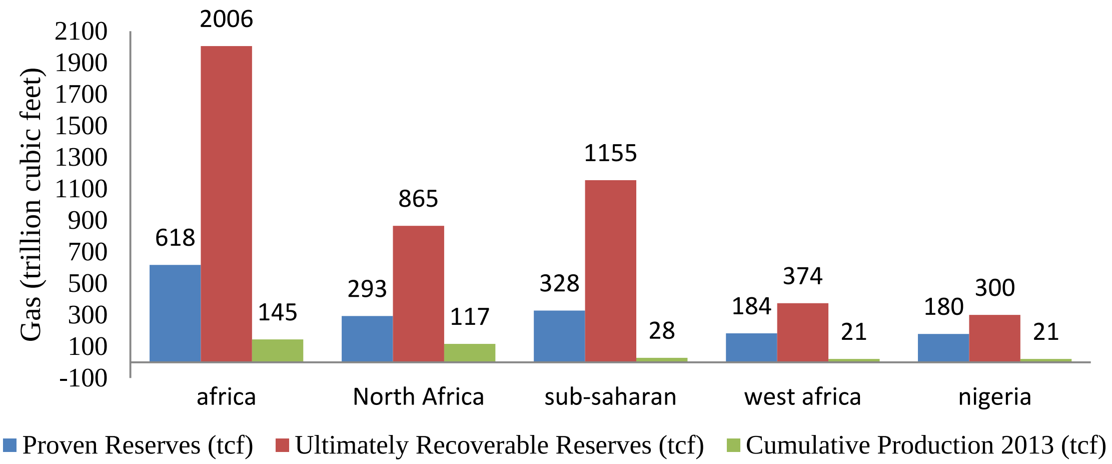


Figure 6: Africa Gas Resources and Reserves (IEA-AEO, 2014)

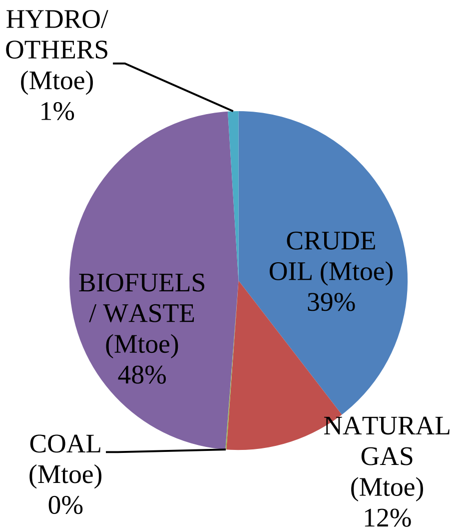


Figure 7: West Africa Energy Production Mix - 2014

Source: Author's computations using data from US-EIA, IEA-AEO, World Bank, CIA

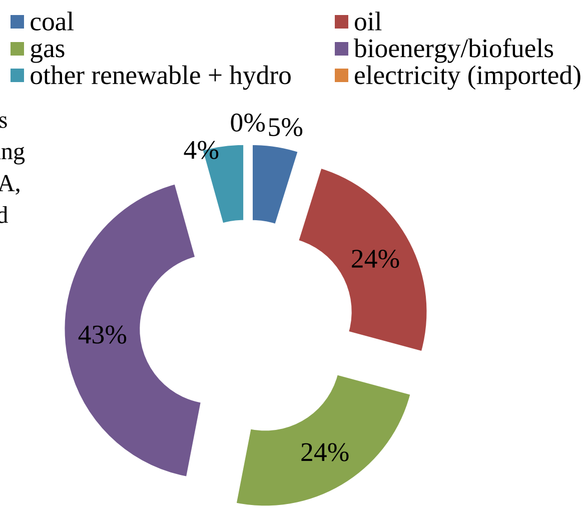


Figure 8: West Africa Total Primary Energy Demand (TPED) projection for 2040

A review of the region overall energy consumption reveals one that is heavily tilted towards biomass/biofuels and oil products which are considered inefficient and un-environmentally friendly. This notwithstanding the fact that the West Africa region generates the lowest CO2 emissions (130 Mt CO_2 in 2015) globally as compared to other regions of the world such as North America, Latin America, Asia, European Union and Middle East. Selected CO2 emissions of some world regions as compared to West Africa region are presented in the table 3 below.
However the primary energy supply resources in the region are mainly utilized for electricity generation, transportation, industrial production, cooking and heating. The region's energy utilization level is clearly less than the total energy reserves and even the production as depicted in the 2014 production and consumption statistics of tables 1a and 1b. Electricity power supply in the West Africa region is heavily dependent on fossil fuels (oil and gas) and this had resulted in high generation costs with many of the countries importing the products. The total grid based electricity capacity in 2014 is estimated at 24,800 MW giving a total average generation of 60.85 TWh with per capita consumption put at 179KWh (IEA-

AEO, 2014). This has been projected to increase to 235KWh by 2020 which is far lower than the 2013 global average of 3,104KWh (Worldbank, 2017; IEA 2016). The electricity share of the total final energy consumption for the same year 2014 is estimated at only 3.7%. This explains the big gap between the average GDP per capita and the average energy consumption per capita in the recent years as shown in figure 9 below. In year 2000 the average GDP at US$392.2 per capita was lower than the average energy consumption at 460.5 kgoe per capita. But in 2009 the average GDP at US$869.6 per capita was higher than the energy consumption at 472.8 kgoe per capita. The gap has become wider by 2014 at US$1,148.9 per capita and 591.8 kgoe per capita respectively. This means that the energy wealth of the region has not been transformed into corresponding welfare and economic growth despite the energy resource base as compared to some other regions given in table 4 below. Despite the huge challenge of developing the electricity generation capacity, the existing systems are facing challenges due to growing gap between existing supply capacities, predicted demand and limited capacity or unified platform to invest. The power shortages lead to regular load shedding and blackouts and in the face of alternative individual power generation options, leads to huge social and economic costs. Many West Africa countries including the main primary energy producers such as Nigeria depend on fossil fuel imports (PMS, diesel, kerosene) and their shortages and fluctuating fuel prices are a major concern for the region. In Nigeria for instance, a larger percentage of the population with electricity access still depend on the non-grid electricity generation satisfied by expensive diesel, PMS or heavy oil.

Table 1a: WEST AFRICA ENERGY PRODUCTION MIX (2014)

Energy Production	Crude Oil (Mtoe)	Natural Gas (Mtoe)	Coal (Mtoe)	Biofuels/ Waste (Mtoe)	Hydro/ Others (Mtoe)
312.20 Mtoe	**123.60**	**36.30**	**0.30**	**149.27**	**3.17**
(3,630.89TWh)	39.6%	11.6%	0.1%	47.8%	1.0%

Table 1b: WEST AFRICA ENERGY CONSUMPTION MIX (2014)

TFC (Mtoe)	Oil products (Mtoe)	Natural gas (Mtoe)	Coal (Mtoe)	Biomass/ Biofuels (Mtoe)	Renewables Hydro /others Mtoe
201.12Mtoe	**32.91**	**15.60**	**0.30**	**149.27**	**3.04**
(2,339.06TWh)	16.4%	7.8%	0.1%	74.2%	1.5%

Data sources: Authors calculation's **World Bank, 2017; US EIA, 2016; Tatsidjodoung et al, 2012**

Table 2: Identified Renewable Energy Potentials

Average generation – GWh (using about 58% utilization efficiency) **Source: IRENA-WAPP, 2014**

	LHP	SHP	Biomass	CSP	PV	Wind 20%	Total
Benin	600	1,021	2,794	0	30,000	1,778	36,194
Burkina Faso	192	711	11,432	18,100	77,400	24,093	131,928
Cape Verde	25	417	737	0	1,682	1,473	4,334
Côte d'Ivoire	4,953	1,230	7,774	2,200	103,000	2,495	121,651
The Gambia	241	61	12,067	3,200	4,740	1,001	21,310
Ghana	2,330	5	5,757	2,300	76,400	3,511	90,302
Guinea	14,296	1,687	3,333	4,700	52,000	12	76,028
Guinea-Bissau	48	10	361	9,000	14,900	721	25,040
Liberia	4,763	5,081	2,332	0	6,670	0	18,846
Mali	2,003	340	5,238	36,200	79,100	11,152	134,034
Niger	1,269	254	5,665	88,300	157,000	84,793	337,282
Nigeria	44,600	17,783	50,808	100,000	325,000	74,632	612,823
Senegal	1,988	528	2,413	15,400	75,200	31,633	127,163
Sierra Leone	4,168	432	843	2,000	15,000	0	22,443
Togo	404	533	2,068	0	21,600	1,021	25,627
Total (GWh)	81,880	30,094	113,622	281,400	1,039,692	238,317	1,785,005

West Africa Energy Use Projections

The West Africa region total primary energy demand is projected to increase to 355 Mtoe (14 quadrillion Btu) by 2040 given an annual growth rate of 2.1% (IEA-AEO, 2014) with natural gas and renewables (hydro, bioenergy, solar, wind) forming over 74% of the total (figure 10). Despite this growth, IEA projection of the primary energy demand by source show fossil fuels (Oil – 76 Mtoe and Gas – 69 Mtoe) to continue to be the major source of energy consumption especially in the transport and electricity generation sector. Growing at an annual average rate of about 5%, natural gas production in the region is equally projected to increase to over 6 trillion cubic feet (tcf) accounting for 81% of the sub-Saharan Africa natural gas growth from 2010 to 2040 (IEA 2013). Over 85% of the West Africa gas production comes from Nigeria, even though the country flares between 11-12 percent of its gross production presently (DPR, 2016). The increasing role of natural gas in the global energy supply mix is not surprising given the considerable concerns over carbon emission by other fossil fuels – coal and crude oil and hence, environmental policies have been in favor of low carbon energy resources.

Table 3: CO_2 emissions of selected countries and regions (2015).

Region	CO2 emission(Mt)	Population (million)
West Africa	130	350
Rest of Africa	1,036	850
Asia	14,798	4,400
China	8,948	1,400
Indian	2,166	1,300
North America	5,704	358
Latin America	1,677	634
Middle east	1,948	200
European Union	3,660	

Source: ENERDATA, 2016

Table 4: Regional Comparison of Average GDP and Energy Consumption Per Capita (2014)

	W.AF RICA	N. AMERICA	U.S	U.K	INDIA	AUSTRA LIA	CHINA
Avg GDP per Capita (current US$)	**1,149**	**54,109**	**54,540**	**46,412**	**1,577**	**61,996**	**7,684**
Avg Energy Consumption per capita (kgoe/CAPITA)	**592**	**6,951**	**6,917**	**2,752**	**642**	**5,485**	**2,252**
Avg Energy Consumption per capita (KWh/CAPITA)	**6,883**	**80,834**	**80,449**	**32,001**	**7,470**	**63,787**	**26,196**
Electricity Consumption per capita (KWh/capita)	**179**	**12,406**	**12,192**	**4,813**	**751**	**9,248**	**3,589**

Data Source: Worldbank, 2017

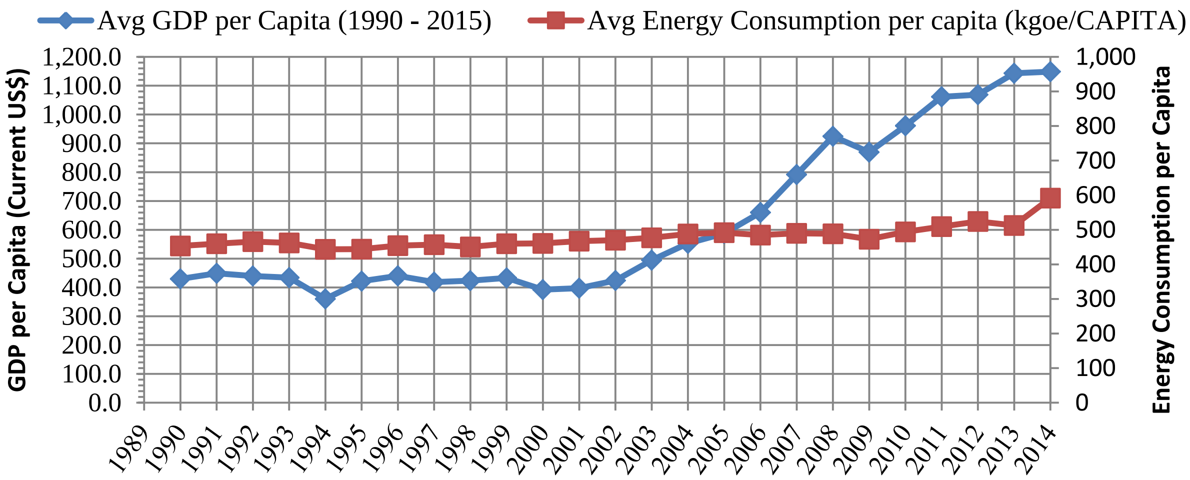


Figure 9: West Africa Average GDP and Energy Consumption per Capita

Source: Author's computations using data from US-EIA, IEA-AEO, World Bank, CIA

Prospects for Natural Gas and Renewable Energy Sources towards Sustainable Energy Access in the West Africa Region

Natural gas fuel has many advantages over other fossil fuels (oil and coal) especially in the area of environmental concerns. It is the cleanest of the three, has lower carbon content, reduced nitrogen and sulphur oxides, particulates and thus lower carbon emissions. It is also known to have lesser cost for generating electricity as compared to oil and coal. And above all, with increasing concerns for the environment and the global protocol for clean energy and low carbon future, many countries are putting policies in place for emission penalties which again has natural gas ranking favorably above coal and oil. Despite these, it still has challenges of its own that includes efficient gathering of the resource for the end-use and its gaseous status making it less transportable to end-use as compared to others. Among these category is "stranded" gas which is the gas occurring in remote and offshore locations that is difficult and expensive and many times un-economic to harness and transport to end-use. It is estimated that more than 33% of global natural gas reserves remain stranded (Thackeray & Leckie, 2002). Despite the stranded nature of some gases, alternative technologies have been developed in recent years to harness and monetize remote natural gas sources such as GTL for transportation, power generation and other petrochemical products (David et al, 2008). At current production rates, the proven reserves of natural gas in West Africa – Nigeria, Ghana and Ivory Coast alone are estimated as capable of lasting well over 100 years (shown in figure 3) these notwithstanding that natural gas potential reserves especially in Nigeria are as high as 600 tcf (EIA, 2009; Aviomoh, 2013). Many of the gas resources currently produced in these countries especially Nigeria are burn-offs (flared) as unwanted by-product of oil production. In 2015, about 290 billion SCF representing 11% of total associated gas (AG) and non-associated gas (NAG) is reportedly flared in Niger Delta of Nigeria (NNPC, 2015; Kazeem, 2017 page 2) and another 2.53 bcf per day of gas is re-injected in Nigeria to boost oil recovery (DPR, 2016; Odumugbo, 2010). The reason for gas flaring in Nigeria for instance has been largely attributed to weak legal and policy framework which provides less or no incentive for gas investment. The laws are not harmonized and these results in no specific direction to reduce gas flaring (Adekamoya et al, 2016). The other reason is attributed to the requirement of extensive investment in gathering infrastructure and transport pipelines for distribution.

Demand increase projection (2012 to 2040) = 81.1%

Source: Author's computations using data from IEA-AEO 2014 new policies scenario)

From gas production statistics and data of West Africa energy consumption, it becomes obvious that gas and efficient renewables have been neglected elements of the region's energy portfolio, despite the resource nearness to many of the countries in the region but rather resorting to more expensive and price fluctuating oil products importation to satisfy its consumption (even though still minimal in the overall total primary energy supply). However with renewable energy abundance and energy efficiency robustness, natural gas could transform the overall energy economy of the West Africa region in decades to come which can be achieved with surmounting some or all of the challenges identified such as strengthening existing policy framework and as well as creating new ones for sustainable energy investment and access across the region. This calls for innovative, collaboration and strategic partnership between the low carbon resources players and the environmental community within the region.

Natural gas lends itself to a range of high efficiency applications, capable of providing the flexible back-up power that will allow high levels of integration and reliance on hydro, wind, solar and efficient biofuels, thereby gradually reducing emissions that would otherwise have resulted in meeting the demand through imported oil products (Flavin &Kitasel, 2010). And luckily the contribution of coal in the overall energy mix in the region is almost non-existent which further creates the appetite for increased natural gas penetration in the region. The region is also at advantage in respect of carbon emissions as illustrated in table 3 which means the best bridge between energy poverty currently experienced and energy prosperity that is advocated as a way of creating the meeting point for global low carbon economy is natural gas fuel.

Several economic opportunities exist for natural gas across the various sectors of the region especially in electric power generation, transport, industrial and residential use. A breakdown of the West Africa energy use by sector (2012 estimates) as presented in table 5 shows that gas is mainly used in the industrial/commercial sector especially for electricity generation. The transport sector is nearly 100% dominated by oil products use in aviation, road and water transport. Substantial portion of the energy use in residential is dependent on less efficient biofuels products mostly wood and charcoal despite the associated health and ecological issues from their utilization.

Table 5: West Africa Energy Use by Sector (2012)

	Industry / Comm (Mtoe)	Residential (Mtoe)	Transport (Mtoe)	TFC (Mtoe)	
Total Final Consumption (TFC)	**25.5**	**120.7**	**16**	**162.2**	
	15.7%	**74.4%**	**9.9%**	**100%**	
coal	0	0	0	**0**	**0.0%**
oil	6	4	16	**26**	**16.0%**
gas	3	0.2	0	**3.2**	**2.0%**
bioenergy/biofuels	13	114	0	**127**	**78.3%**
other renewable + hydro	0.5	0.5	0	**1**	**0.6%**
electricity (imported)	3	2	0	**5**	**3.1%**

Source: Author's calculations using data IEA-AEO, 2014 new policies scenario; Tatsidjodoung et al, 2012

Figure 10 shows the West Africa energy use by fuel in 2012 as well as the IEA projected demand for 2040. The 2040 scenario unfortunately appears to project a West Africa that is heavily reliant on oil products for transport and moderately for the residential sector over gas products, the use of gas is projected to increase considerably in the industrial and commercial sectors. Importation of electricity across the region is also projected to increase considerably. Despite these projections, it can be emphasized that the systemic development and growth of gas products consumption through regional harmonized, consistent policy and robust regulatory framework would change the access of energy to the sustainable and low carbon economy supported by gas and renewable energy resources. The emerging revolution in the transport sector through electric vehicles (EVs) which can be underpinned in improved or new solar technologies has already seen some countries such as Netherlands, Norway and Germany making legislations by way of providing the regulatory framework to allow quick penetration of near zero-carbon emission transport systems.

Natural gas being a robust fuel, its use across the major sector applications would be yardstick for robust energy access. In the developed economies such as USA and UK, gas represents a significant portion of the primary energy consumption. It represents about 29% of the U.S. energy mix in 2015 (US-EIA, 2016) and 28% of UK 2014 total energy consumption (CarbonBrief, 2015). Despite the heavy use of oil products in the transport sector, gas use as vehicle fuel (liquefied natural gas-LNG and compressed natural gas-CNG) is gaining importance and popularity across the world.

Taking a cue from the developed economies such as U.S. and UK, a higher share of the energy demand in the region can be satisfied with gas fuel. The major sectors that higher penetration can be achieved include the power generation, residential cooking and heating and industrial production and heating.

West Africa through regional collaboration would need to significantly improve its electricity generation and supply so as to enhance overall energy access for the growing population and provide means for economic growth (IRENA-WAPP, 2013, page 13). In power generation, substantial share can be satisfied through gas based generation. Already over 37 percent of grid electricity is generated from gas fuel as evidenced from figure 11. With augmentation from the renewable resources such as hydro (large and small), solar and bioenergy, it is possible to achieve over 80% of total power generation (IRENA-WAPP, page 50) particularly starting with the gas producing countries – Nigeria, Ivory Coast and Ghana. In Nigeria for instance, the gas-to-power program of the government projects over 80% of electricity generation to be satisfied with gas and renewable resources in 2025 with zero percent oil share (NESP, 2014). In Sierra Leone, the percentage share of renewable energy sources (mainly hydro and solar power) in the county's electricity generation in 2013 was 49.9% (EU-ICD, 2016). The gas-to-power program of Ivory Coast currently has in its portfolio to deliver a 375MW combined cycle gas-power plant in 2018 with plans to increase its capacity to 1200MW (PEI journal, 2016). In addition to the development of a regional gas network, the West Africa Power Pool (WAPP) would be another avenue to propagate the generation of electricity from gas through a Gas-to-Wire collaboration program.

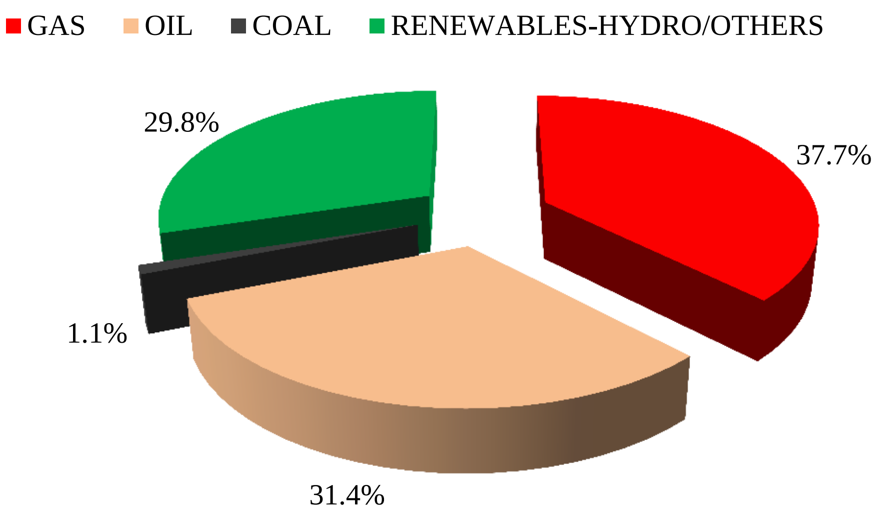


Figure 11: West Africa Electricity Production by Fuel, 2014
(sources: Author's computations using data IEA2014, EU-ICD, WORLDBANK, 2017; CIA, 2017)

Presently production costs of electricity vary from one country to the other depending on the major fuel source and the purchasing power parity of each of the country. Despite the widespread of hydroelectricity generation which is still below optimal utilization, imported oil (for instance diesel power generation) constitutes the major part as estimated in figure 11 representing about 31 percent of the total electricity generation by fuel in West Africa. A look at the electricity generation in some of the West Africa countries as depicted in figure 11 shows Cote d'Ivoire and Nigeria highly reliant on gas and hydro power for available grid-electricity forming about 90% of generation (IRENA-WAPP, 2014). Ghana has about 36% generation from fossil-oil, 9.5% from natural gas and about 55% from hydro and other renewables for grid-power electricity generation. The rests are heavily dependent on fossil-oil based grid-power generation. However these do not take into account the individual power generations supported by expensive emergency generations that make up the bulk of electricity access for these countries especially Nigeria. Using a typical case of Nigeria an average household has a standby power generation set and installation of standby power generation is taken as standard for almost all the business entities – financial institutions, hospitals, schools, network operators-base stations, small scale and medium enterprises (SMEs), industries, government parastatals and ministries. A survey of the average effective electricity tariff in Africa in 2010 (ADB, 2013) indicates a cost of about US$0.14 per KWh (subsidized by many governments) as compared to the average production costs put at US$0.18 per KWh. The average electricity tariffs (US$ per kWh) in comparison with some selected regions are

India – 0.08, China – 0.08, Canada – 0.10, United States – 0.12, Russia – 0.11, South Africa – 0.10, UK – 0.20, Spain – 0.30, Germany – 0.35 and Denmark – 0.41 (Ovoenergy.com, 2011). As expected, the higher cost in Denmark is attributable to the existence of small island countries that are dependent on imported diesel for power generation. Using the current 2017 costs of oil products in Nigeria for instance, the cost of Gasoline (PMS) is US$0.46 (N145) per litre and diesel oil is US$0.66 (N220) per litre. The average household runs the power generator for about 4 hours a day consuming an average of 15 litres of PMS or about 10 litres of diesel fuel which translates to US$6.90 (N2,200) for PMS or US$6.60 (N 2,130) for Diesel. In comparison, the average household consumes about 4.4KWh of grid power for about 4 hours. The cost of grid electricity is currently N31.8 per KWh (about US$0.10 based on current exchange rate of N318 per US$) giving approximately US$0.46 (N145) for 4 hours. This means that the average household pays between US$207 (N66,000) in a month to generate low and inefficient electricity in 4 hours per day as compared to about US$13.8 (N4,350) per month to access 4 hours per day of electricity from the grid. This is estimated to be 16 times higher in cost than that of the grid. Similar costs of gasoline and diesel in some selected West African countries are shown in table 6 below. The high production costs of electricity as a result of using expensive oil and increasing dependence on it is unsustainable especially with the rapidly growing population of the region estimated at 650 million in 2040 as against the 2015 estimates at 350 million (UN, 2015). It can then be explained that sustainable access to quality energy would be a mirage under these circumstances. And this is where natural gas plays a major role and as a complement to the already existing array of renewable energy resources.

Table 6: Fuel Prices in West Africa States (2017)

Country	Gasoline (US$/Litre)	Diesel (US$/Litre)	Country	Gasoline (US$/Litre)	Diesel (US$/Litre)
Benin	**0.85**	**0.83**	**Liberia**	**0.79**	**0.8**
Burkina Faso	**0.89**	**1.02**	**Mali**	**1.03**	**0.8**
Cape Verde	**0.87**	**1.10**	**Niger**	**0.91**	**1.18**
Côte d'Ivoire	**0.97**	**0.49**	**Senegal**	**1.01**	**0.46**
Ghana	**0.92**	**0.92**	**Sierra Leone**	**0.49**	**1.18**
Guinea	**0.86**	**0.86**	**Togo**	**0.89**	**0.49**

Source: Globalpetroprices.com

A larger percentage of the total primary energy consumption across the region is in biomass/biofuels for cooking and heating mostly in the residential and commercial sector. The region's dependence on the biomass and biofuels in these sectors averages over 74 percent as evident from table 1b. The prospect for natural gas in this sector as clean cooking and heating fuel is very huge and can favorably be integrated with the option of pursuing and promoting cleaner burning stoves using cooking fuels such as biogas, ethanol, LPG, gel fuel and charcoal.

The transport sector which is presently ruled by oil products can substantially be penetrated by gas based products – CNG and LPG. In Nigeria for instance CNG awareness and use is currently growing in popularity in road cars and trucks. It is however foreseen that its development in this sector would be slow as oil products may continue to dominate for a long time. CNG in vehicle for instance has a drawback of producing 3.5 times shorter range than gasoline or diesel for the same volume of tank and also requiring a higher pressurized tank (Demierre 2015). Because of higher prices for imported oil products CNG and LNG could offer a cheaper alternative in addition to its lower emission levels.

There is equally a very huge market for natural gas in the industrial sector in areas such as fertilizer, cement, petrochemical, methanol, CNG and LPG.

Generally, Nigeria given it several strategic placement in terms of population, resource production and use, it is considered that Nigeria should be positioned as the regional gas based hub for the overall gas use. Evidence of resource use appetite is shown in figure 12 – West Africa energy use by country.

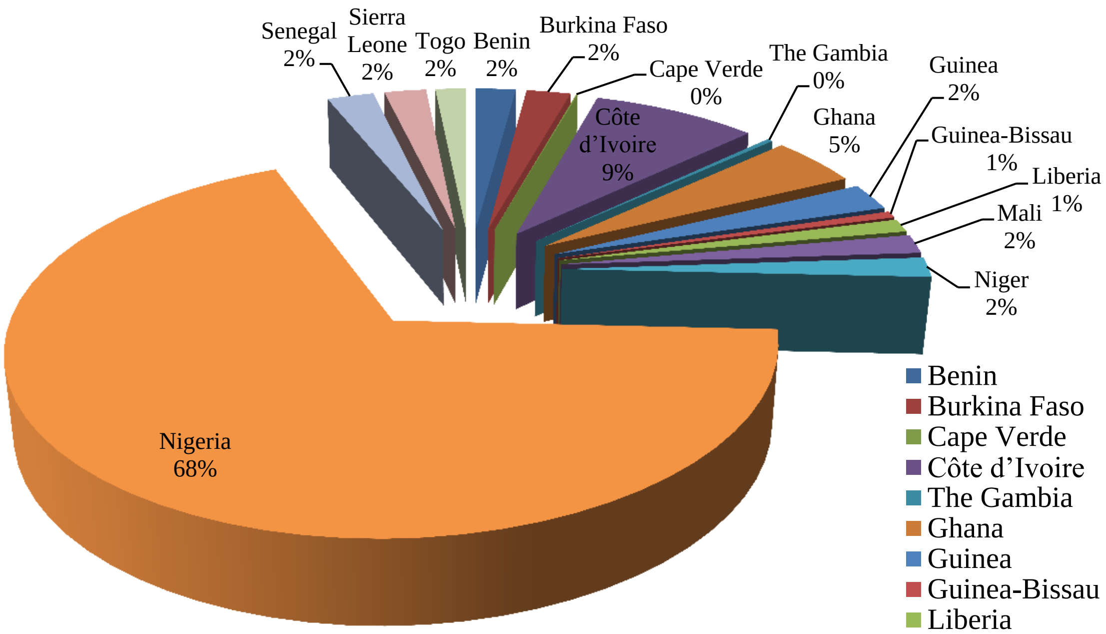


Figure 12: 2014 West Africa Energy Use by Country (source: World Bank, 2017)

The Way Forward

The role of gas in the energy prosperity of West Africa therefore need not be overestimated. The prospects in a region that is grossly underdeveloped in energy access even in the face of energy resources abundance are enormous. Electricity supply and access within a population is known for instance to create significant means for economic growth and overall welfare. Given the enormous renewable energy potential in West Africa region, systemic integration of natural gas use (at the expense of the other fossils – oil and coal) into the overall energy system would be required to provide the affordable and secure energy access while achieving a low-carbon economy with reduced carbon emissions. This would generally require long term vision planning and consistent implementation to make the best use of the low-carbon resources while gradually and consistently decreasing the use of high carbon fossil fuels – oil and coal across all the energy consumption chain – industrial, domestic, power generation and even transport.

Energy access in the region which varies from one country to the other is not without its challenges. And having identified that increased natural gas use is a major determinant of the sustainable access, some specific challenges identified that shall be surmounted to unlock the potential benefits include low level of gas delivering infrastructure, insecurity, un-harmonized gas pricing structure, poor contract sanctity, lack of storage facilities, un-harmonized gas market structure and low level of gas production. The biggest of the challenges as agreed by many analysts [Demierre, 2015, page 431; Masud et al 2015 page 776] to which many of the challenges are linked is absence of a robust regional policy strategy and regulatory framework. We therefore make the following recommendations: First the region will require a harmonized, robust and dedicated policy strategy and regulatory framework on energy development within the region. Using the already existing ECOWAS platform, liberalization of the West Africa electricity and the national gas markets of Nigeria, Sierra Leone and Ghana would require development of effective competition in a fully functional market. It will involve the establishment of a common energy market regulatory and policy implementation agency which deals primarily on market protection and growth ensuring transparency and accountability. For instance the ECOWAS WAPP body created to promote and develop infrastructure for power generation and transmission among West Africa states is a right step in this direction that needs to be built on.

Good price adoption mechanism for gas trading within the regional context is considered as the next most important step required for the successful implementation of sustainable energy access. Gas pricing mechanisms such as the ones adopted in the U.S (henry hub), UK (the national balancing point-NBP) and Netherlands (Title transfer facility-TTF) – constitutes relatively and highly competitive gas markets

[Hulshof et al, 2016] which encourages gas development and positively influences the overall energy security of these regions. The gas pricing structure currently in West Africa and a larger extent in Nigeria is far from being competitive, lacks economic incentive to invest [Agbonifo, 2105] and makes harnessing of gas resources un-attractive [Odumugbo 2010, page 314]. The adoption of a flexible market for investing and trading in natural gas, the one that is capable of creating opportunities for spot and future gas markets in the West Africa region is recommended. Given the high disparity in GDP per capita and purchasing power parity (PPP) among the countries of the region, it is foreseen that a flexible market is capable of making dozens of gas locations (power supply, CNG and LPG stations) thereby enabling price discovery and gas-to-gas indexed contracts.

The above without doubt is based on a solid backbone for gas infrastructure. Roger et al (2016) recognizes the need for a natural gas pipeline network to be flexible and complex. The flexibility and complexity in addition to the pipeline capacity serving the market are considered to largely determine the success of a regional market and gives the question of whether the regional markets interact to form a smoothly functional market. The pipeline capacity in respect to size is a major determinant of the quantity of gas that can be delivered at any given time to meet demand. Though the economics of gas transportation through pipeline is a function of distance as the longer the distance the more the unit cost, the success story of other regional gas networks is enough to spur substantial motivation for the West Africa energy security through investment on natural gas networks.

Nigeria with the largest population as well as the biggest consumer of energy (figure 12) has the highest gas pipeline network in the region and still expanding, and is considered to hold the key to unlocking the energy potentials of the region. Typical gas pipeline projects that have been attempted in the region includes the 680km West Africa gas pipeline (WAGP) which links Nigeria and Ghana through Benin and Togo (though has performed below expectations in gas delivery) and the 2500km Trans-Sahara Gas Pipeline planned to connect Nigeria and Algeria to serve the European Market (project initiative of Nigeria and Algeria). The region can substantially leverage on the gains made in these already existing networks as well as the planned ones. As compared to some of the regional gas networks such as the 3,150km x (16" to 32") Bolivia – Brazil gas pipeline (GASBOL) delivering gas to Brazil from Rio Grande, Bolivia, capacity of 390 BCF per year and 2800km x 56" Atai gas pipeline from Russia's Western Siberia to North-Western China (planned) for capacity of 1,059 billion cubic feet of gas per year, the distance between Nigeria Lagos and Senegal Dakar is approximately 3,000 km along the West Africa coast. This further creates the appetite to extend the WAGP gas pipeline given that the appropriate conditions are enforced. The absence of a regional energy integration system is therefore considered to hamper economies of scale that should permit lower costs across all aspects of power infrastructure and robust electricity exchange. Estimate show that regional collaboration could reduce electricity costs in Africa by US$2 billion per year (ADB, 2013). Lower prices of natural gas (mostly indexed to oil prices) are creating more incentives for producers to target markets closer home. For instance Asian LNG spot prices fell to about US$5.86/MMBtu – May 2016 from US$18.11/mmBtu in July 2012 (YCharts.com, 2017). The WAGP supplied gas to consumers in Ghana at US$8.60/MMBtu (2016) while Ghana NGC gas (retailed at US$8.84/MMBtu), yet gas edge over oil in electricity generation (Ghana Ministry of Petroleum, 2016). In comparison, US Henry Hub (average spot) fell to US$1.60/MMBtu – March 2016 from US$4.80/MMBtu – January 2014 (US-EIA, 2017) and the EU import price from US$12.88/MMBtu – April 2013 to US$4.04/MMBtu – May 2016 (YCharts.com, 2017).

Conclusion

For a region that has a population of about 350 million people (UN, 2015) which is 4.8 percent of the global and a projected increase to about 650 million people in 2040, the energy demand estimates up to 2040 are expected to be more than 355 Mtoe (14 quadrillion Btu), an over 80 percent increase from 2015 estimates. Given this enormous growth, it is only critical that the energy security vacuum must be filled with the consumption of sustainable energy resources that guarantees the future in protecting the environment, increase welfare and improve economic development. Natural gas has been identified to play a significant role in satisfying that demand and even exceeding it being able to substantiate as the base load fuel for energy access while renewable energy resources that are abundant and spread across the region are systematically being increased. The increased consumption of natural gas is expected to reduce the dependency on oil and inefficient biomass resources consumption and may result in energy security, overall welfare, increased economic growth and reduced environmental impact. The prospects and opportunities for natural gas across the West Africa region has been identified in electricity generation (main user), residential, commercial and industrial sectors. Even higher prospects exist in the transport sector. The results of this study indicated large natural gas resource potential that is sufficient to satisfy the projected total primary energy demand and for a long time. This notwithstanding the natural gas resources around the West Africa region found in Mauritania and Algeria that can be leveraged on for easy access given that the right business environment is established. The vacuum between reserves and production of natural gas in the region is wide, and production in the Sub-Saharan Africa is known to be the lowest globally[1].

We arrive at the conclusion that resource abundance alone especially gas and renewables is not enough to guarantee security of supply and subsequent access that is sustainable. This has already been evidenced by the severe energy poverty that is presently existent in the region despite abundance. Therefore the robust regional policy strategy and regulatory framework must be put in place as a matter of regional urgency. The policy must be guarded to be transparent and competitive enough to encourage investment in gas development and supply, and robust electricity supply exchange. Individual country policy strategies on renewable energy development should be ensured and the roadmap for integration into the overall energy plan must be monitored.

Bibliography

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SHP – Small Hydro Power
CNG – Compressed Natural GAs
LNG – Liquefied Natural Gas
ECOWAS – Economic Community of West African States
WAGP – West Africa Gas Pipeline
WAPP – West Africa Power Pool
MMBtu – Million British Thermal Units

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