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Developing compressed natural gas as an automotive fuel in Nigeria: Lessons from international markets

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HIGHLIGHTS

- We examined the NGV policies and implementation strategies in selected countries.
- The use of legislative mandates help deepen NGV penetration.
- Aligning stakeholder interest is critical to NGV adoption.
- Making national interest a priority ahead of regional infrastructure is a critical success factor.
- Government support drives participation.

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ABSTRACT

The Nigerian government proposed the use of compressed natural gas (CNG) as an automotive fuel in 1997 as part of the initiatives to harness natural gas (NG) resources but progress has been slow. This paper examines the natural gas vehicle (NGV) implementation approaches and outcomes in seven countries with diverse experiences in order to gain an understanding of the barriers to the NGV market development in Nigeria. The analysis employs hermeneutic principles to secondary data derived from academic literature, published reports from a variety of international agencies, grey literature, and text from online sources and identifies eight success factors for NGV market development namely: strategic intent, legal backing, learning and adaptation, assignment of responsibilities, financial incentives, NG pricing, consumer confidence, and NG infrastructure. The paper concludes that the principal impediment to NGV market development in Nigeria is the uncoordinated implementation approach and that greater government involvement is required in setting strategic goals, developing the legal and regulatory frameworks, setting of clear standards for vehicles and refuelling stations as well as assigning responsibilities to specific agencies. Short-term low cost policy interventions identified include widening the existing NG and gasoline price gap and offering limited support for refuelling and retrofitting facilities.

1. Introduction

Nigeria is the world's 10th most populous country (World Bank, 2014), the 6th largest producer of crude oil, the 7th largest natural gas (NG) reservoir and the 4th leading exporter of liquefied natural gas (LNG) (EIA, 2013). The country is endowed with 187 trillion cubic feet (tcf) of proven reserves of high quality NG that is rich in liquids and low in sulphur; most of which is associated gas (AG), found during oil exploration and production (NLNG, 2011). Oil and gas exports account for over 98% of export earnings and are the major drivers of the economy which is the largest in Africa and the 26th largest in the world with a GDP of $522.6 billion in 2013 (World Bank, 2014).

Nigeria faces two major challenges relating to its oil and gas assets: firstly, fugitive emissions, i.e. the intentional and unintentional release of greenhouse gases (GHG) during the extraction, processing and delivery of oil (World Bank, 2004) and secondly, energy vulnerability characterised by frequent power outages and persistent domestic shortages of refined petroleum products (EIA, 2013).

Fugitive emissions result mainly from the disposal[1] of AG

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[1] Until recently, AG was considered as a by-product to be disposed for safety considerations.

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through venting[2] and flaring.[3] These create social and environmental problems and result in the waste of valuable natural resources (World Bank, 2004). Nigeria produced 8529 mbbls of crude oil and 22 trillion standard cubic feet (tscf) of AG between 2003 and 2012, an average[4] of 2.5 thousand standard cubic feet/barrel, and flared 7.2 tscf or 32.87% (NNPC, 2013). The country contributes between 10 and 15% of global flared volume and is consistently ranked second after Russia (World Bank, 2011). Estimates suggest losses of up to $72 billion in unearned revenue between 1970 and 2006 due to gas flaring (The ERA Fact Sheet 2008, cited in Bassey, 2008).

As a result of gas flaring, fugitive emissions constitute the largest source of energy related GHG emissions (31.34%) of which Methane is dominant (50.76%); unlike most countries where CO_2 dominates (WRI, 2010). This presents long-term socio-economic and environmental risks as hydrocarbons have significantly higher impact on public health and a greater potential for global warming and climate change than CO_2 (IPCC TAR WG1, 2001).

To abate flaring, the country initiated efforts to exploit the AG for NG export, domestic power generation and transportation, and as industrial feedstock. Major initiatives include the Nigeria Liquefied Natural Gas Limited (NLNG) that has exported over 3.7 tcf of LNG (NLNG, 2013), the Oso Condensate Natural Gas Liquefaction, the Brass River LNG – the first offshore LNG plant in the world (Alexander's Gas & Oil Connections, 2003), the Olokola LNG plant, the Escravos Gas Projects for LPG and the Escravos Gas-to-Liquids facility. There are three gas turbine power plants (Afam, Egbin and Okpai) and two gas-fired thermal plants (Ughelli and Sapele) and 17 other gas power plants at various stages of construction. International pipeline projects include the 678 km West African Gas Pipeline (WAGP) which runs from Nigeria to Ghana and the proposed Trans-Saharan Gas Pipeline (TSGP) which is planned to terminate in Algeria. Domestic pipeline projects include the Oben-Geregu pipeline which is to supply a power Plant, the Obiafu-Obrikom-Oben pipeline intended to connect the western and eastern parts of the country, and the Escravos to Lagos Pipeline System which would increase supply capacity to the South Western part of the country.

These initiatives have contributed to the reduction in the percentage of gas flared from 77% in 1990 to 23% in 2012 (NNPC, 2001, 2013). However, satellite images indicate that the absolute volume flared has increased (WRI, 2010).

Nigeria has a crude oil distillation capacity that exceeds domestic demand but imports over 80% of the refined products consumed locally because of low refinery utilisation rates (EIA, 2013). Energy vulnerability is further compounded by the large and growing population and government subsidy on the pump price of petroleum products.

Nigeria has witnessed increases in energy demand and GHG emissions in all sectors between 1960 and 2013 as the population grew from 45.2 million to 173.6 million (384%) with a significant urban drift from 14% to 50% and per capita income growth from $580 to $1100 (World Bank, 2014).

The prices of gasoline and kerosene are regulated and subsidised by up to 40% while that of diesel is deregulated following the withdrawal of subsidy on the product in the early 2000s. The subsidy administration is fraught with corruption, ineptitude and inefficiency (Mark, 2012) and this sometimes results in delays in the imports which in turn results in perennial fuel scarcity. The NNPC, which hitherto was not involved in downstream operations, initiated a Mega Station scheme to address the supply gap but the intervention has not solved the problem.

The foregoing calls for a holistic rethink in the efforts to exploit NG especially as existing efforts have focused on export and domestic use for power and industry. However, in the transport sector, despite the government's proposal in 1997 to adopt CNG as automotive fuel, of 5,686,485 registered vehicles in 2013 only 2210 are NGVs (NGVA Europe and the GVR, 2013).

The objectives of this research are, to identify the barriers to the NGV market development and identify ways forward based on the expectation that the automotive use of CNG provides an opportunity to significantly reduce the emissions inventory, reduce gas flaring and increase domestic gas utilisation.

Studies including Collantes and Melaina (2011), Nijboer (2010) and Yeh (2007) have examined NGV adoption strategies for various countries but studies on Nigeria are sparse and focus on other areas e.g. Nwaoha and Iyoke (2013) which assessed the viability for emissions reduction. This study will contribute to the discussion of the CNG programme in Nigeria particularly with respect to the barriers to market development and pathways towards successful implementation and provide lessons for oil rich developing countries and countries experiencing rapid urbanisation in their efforts to deploy NGVs in particular and alternative fuels vehicles (AFV) in general.

The paper is organised as follows: Section 2 draws on evidence from the wider literature on the potential of NGVs; Section 3 outlines the methodology; Section 4 presents the country analysis; Section 5 the cross-country analysis and Section 6 the conclusions and policy implications.

2. NGV potential

The global NGV population grew from 415,855 in 1991 to 16,733,098 in 2012 with much of this growth occurring between 2003 and 2012. The Asia-Pacific region had the most growth (35.7%), while North America, declined by 0.9% and Europe, Latin America and Africa grew by about 15% each (NGV Global, 2012). The top 10 countries with the highest NGV population, Iran, Pakistan, Argentina, Brazil, China, India, Italy, Ukraine, Columbia and Thailand, accounted for 87% of global NGVs and 70% of refuelling stations (ibid.).

Economic benefits, environmental considerations, energy security, and NG availability are the major drivers for NGV adoption (Pike Research, 2012 and Yeh, 2007). The three, main policy instruments are vehicle technology and fuel regulations, consumers and/or suppliers incentives and market creation focused on government fleets and direct investment in infrastructure (Yeh, 2007).

NGVs offer superior engine performance compared to gasoline and diesel equivalent because NG has higher octane and lower cetane numbers and does not require anti-knock additives (Oando, 2014). The horsepower, acceleration, and cruise speed are also comparable (DOE, 2013; NGVi, 2013; SCGC, 2013). A major disadvantage is the lower driving range resulting from the lower energy density of NG. Nonetheless, this can be increased by providing extra storage cylinders albeit at the detriment of cargo volume.

NG reduces GHG emissions by 15–25%,[5] eliminates evaporative emissions,[6] produces little or no particulate matter and shows a reduction of up to 80% in ozone-forming emissions compared to gasoline (NGVAmerica, 2013 and Marbek, 2010). Many studies e.g. Goyal and Sidhartha (2003), Mena-Carrasco et al. (2012),

[2] Discharge of the entire constituent of AG, predominantly methane into the atmosphere.

[3] The burning of AG during discharge which emits gases that range between raw NG and ideal methane combustion emissions of water vapour and CO_2 due to inefficiency (Buzcu-Guven et al., 2010).

[4] This provides only a quantitative context. The Gas Oil Ratio and the composition of AG depend on multiple factors e.g. Nature and the degree of depletion of the reservoir and the type of lift used (PFC Energy, 2007).

[5] Depending on the vehicle segment with the greatest reductions occur in medium and heavy duty, light duty and refuse truck segments (Marbek, 2010, p. 32).

[6] Responsible for at least 50% of hydrocarbon emissions in conventional vehicles.