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Review Assessment of Current Status, Challenges, Opportunities, and Implications of Liquified Natural Gas Supply Infrastructure Development in the Nigerian Maritime Sector

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ABSTRACT: The maritime sector in Nigeria plays a pivotal role in the country's economic growth and trade activities. As part of Nigeria's commitment to clean energy and sustainable development, the development of liquefied natural gas (LNG) supply infrastructure has emerged as a critical component of the nation's energy and transportation strategy. This article reviews an assessment of the current status, challenges, opportunities, and implications of liquified natural gas supply infrastructure development in Nigeria's maritime sector by qualitatively harvesting secondary data from several sources. The paper recommends the provision of LNG bunkering facilities at Lekki deep seaport.

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The marine ecosystem's sustainability could be achieved by using clean fuel to drive marine crafts and LNG is one of the clean fuels to lead the marine ecosystem sustainability. According to PricewaterhouseCoopers (www.pwc.com/ng), natural gas is expected to surpass coal as the world's fastest-growing fossil fuel and become the second-largest energy source after crude oil by 2030. Nigeria's estimated gas reserve will rise to 210.8tcf, making it the African gas hub if the required infrastructure is implemented (www.pwc.com/ng). Nigerian-produced gas could either be domestically used for electricity generation, industrial heating, gas-based industries feedstocks, and natural gas fuel or exported to other countries (www.pwc.com/ng). According to Okafor (2021), the NNPCL (Nigeria National Petroleum Company Limited) projected that Nigerian demand for Natural gas will rise to around 23bcf (billion cubic feet) per day by 2030. Nigeria has an annual production of 3,009,650.25MMCF (Million Cubic feet) which places Nigeria as the 12th in the world in natural gas production Okafor (2021), and the first in natural gas reserve in the whole of Africa at about 200 trillion cubic feet (https://www.statista.com/statistics/1197585/natural-gas-reserves-in-africa-by-main-countries). According to Okafor (2021), domestically 8bcf/d is consumed for power generation, 0.7bcf/d for gas-based industries use and 3.2bcf/d is exported via shipping and West Africa Gas Pipeline (WAGP), and around 54bcf/d is

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flared Okafor (2021). Generally, the concern for ship emissions has generated to conventions by IMO on the reduction of ship emissions to a minimum standard Brett (2008). The 2018, IMO strategic adoption to reducing greenhouse gases GHGs from the maritime sector globally as a transition which requires little or no carbon fuel (Pavlenko *et al.,* 2020). By 2050, the GHG emission from the global marine transport will be cut by half. This is following the Paris convention agreement as the present GHG emission is around 3% (Lindstad *et al.,* 2020). To achieve a decarbonized shipping environment, LNG is recommended as a transitional fuel (Lindstad *et al.,* 2020). LNG is considered based on its ratio of hydrogen to carbon Lindstad *et al.,* (2020), because its carbon per unit of energy is relatively less when compared with other conventional marine fuels (Pavlenko *et al.,* 2020). Furthermore, the low carbon emissions of LNG when compared to other marine fuel like Marine Gas Oil (MGO) or Heavy Fuel Oil (HFO) is considered very negligible (Lindstad *et al.,* 2020). Therefore, it is generally believed that the use of LNG reduces the global warming impact in the marine environment and ecosystem in general. This argument re-enforces the need for LNG to be considered as a transition fuel. The systematic progression to using low carbon fuels and innovative technological engines from fossil fuel is referred to transition (Lindstad *et al.,* 2020). Comparing the lifecycle emission with other fuel based on shipping, extraction, production and power generation especially black coal, LNG produces greenhouse gas emission of 40% by 2030 (Fogarty 2011). Furthermore, LNG produces less fumes, soot or duct with minimal eco- system damaging sulphur dioxide (so2) and nitrogen oxide (Nox) emission having less carbon dioxide generated at 30% less than fuel oil (https://www.elengy.com/en/lng/lng-an-energy-of-the-future.html). Energy efficiency and yield thermodynamics makes LNG the best basic energy with the low environmental impact to the ecosystem (https://www.elengy.com/en/lng/lng-an-energy-of-the-future.html). However, the cost efficiency of LNG when compared with other Marine Gas Oil (MGO) with low–sulphur content is more competitive (https://www.elengy.com/en/lng/lng-an-energy-of-the-future.html). Furthermore, the economic and cost drivers in the use of LNG as marine fuel include fuel cost, availability, repowering and new builds (World LPG Association 2019). The low pricing of LNG on a heat value basis than Heavy Sulphur Fuel Oil (HSFO) is un-comparative advantages while the uncertainty lies with the future price of LNG (World LPG Association 2019). Xu *et.al*., (2015), advocated for the use of LNG on inland vessels fuel which needs to be addressed at regulatory level. The need for clean energy in the maritime sector should cut across other areas in the sector, ranging from fuel for ocean-going vessels to fuel for offshore platforms for electricity generation to fuel for little marine crafts and inland vessels such as offshore marine service vessels together with fish trawlers. The sustainability of waterborne transportation is key to the maritime world considering, LNG as a transition fuel in inland waterways navigation, deep-sea voyages and short-sea expeditions (Aronietis *et al.,* 2016). As Marine Gas Fuel is gradually been replaced by LNG, there is a need for Port authorities to know the transition energy demand to assist them in the provision of LNG bunkering infrastructure to meet inland, deep-sea, and short-sea voyages by vessels (Aronietis *et al.,* 2016). Furthermore, as ship owners follow the transition fuel trend, it's of importance the ports play their part in the provision of the necessary LNG bunkering infrastructure to meet demand (Aronietis *et al.,* 2016). Adamchak and Adede (2013) cited in (Aronietis *et al.,* 2016), projected LNG marine fuel demand for 2020 at 1 million tonnes while by 2025 to be 8.5million tonnes. The projection showed a significant increase in demand. However, Aronietis *et al.,* (2016) citing Adamchak and Adede, (2013), projected demand for LNG bunkering ranges from 8 to 33million tonnes in 2020; from 0.7 to 66million tonnes by 2025; while above 65million tonnes by 2030.

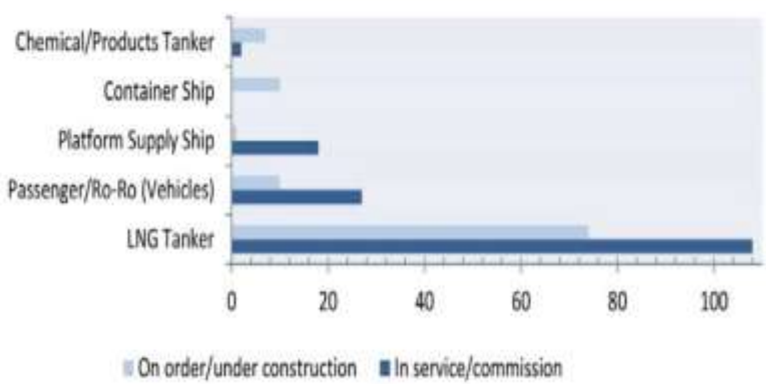

Fig 1: LNG powered fleet by status
Source: IHS Maritime database (2015) cited in Calderón et al., (2016)

This progressive world projection certainly calls for the development of LNG bunkering infrastructure by port authorities. Figure 1 presents the number of LNG-fueled fleet from 2016 - 2021 in service at 196 while in-order is 133 vessels IHS Maritime database (2015) cited in Calderón *et al.,* (2016). Presently 251 LNG-fueled vessels are in operation and around 403 vessels are on order (Editorial Team 2022). There will be an increase in the number of LNG-powered vessels in operation in the coming number of years considering the progressive pattern between 2016- 2021 and presently.

The consequence of the increase in the number of LNG-powered vessels in operation and the ones yet to be commissioned is a need for the development of LNG bunkering infrastructure. The aim of this research is to ascertain the preparedness of Nigeria's authority in providing LNG bunkering facilities for ship fueling considering its enormous market and production advantage. Submissions of Yahya and Nkwatoh (2021) suggested that investment in gas supply infrastructure would increase the usage of gas through LNG production, gas-based industrial use, and power generation, as well as prevent gas flaring and promote national growth. Furthermore, Dummy linear models were used by Ojide *et al.*(2012), to examine the structure of gas flaring and the impact and sustainability of gas use, their findings revealed that gas use has a large beneficial influence on the economy and is also sustainable. The increase in demand for sustainable energy is leading ports around the world to develop LNG bunkering facilities (Berti, 2020). Europe was the first region under the IMO charter agreement to implement LNG bunkering with the establishment of the first Sulfur ECAs in 2006 and 2007, the European Union mandates that a core network of inland ports and a core network of marine ports be ready to provide LNG bunkering by 2030 and December 2025, respectively (European Union, 2014).

Presently according to https://sgp.fas.org/crs/misc/R45488.pdf, coastal ports in European countries of Spain, France, and Turkey as well as the North and Baltic Seas together with renowned port cities like Rotterdam, Barcelona, Marseilles, and London have 40 LNG bunkering infrastructure while 50 more LNG bunkering facilities are under construction in the ports across Europe. America has its LNG Bunkering Facilities in the ports of Montreal, Jacksonville, Port Fourchon, Panama, and the Dominican Republic (Berti, 2020). In Asia, we have ports in Singapore, Kochi, and Yokohama that have developed super LNG bunkering Facilities (Berti, 2020).

Within the current and available literature, no work has been done in evaluating LNG bunker infrastructure provisions in ports in Nigeria, hence this work. For oceangoing vessels to use LNG as an engine fuel, the presence of LNG bunkering facilities is a critical need based on LNG's extreme coldness (-260 °F) and instability, which requires specialized infrastructure for supply, storage, and fuel delivery to vessels (https://sgp.fas.org/crs/misc/R45488.pdf.). LNG bunkering could be done either by truck (road Tanker) to LNG Fueled ship (RTS); Shore (LNG Terminal) to LNG Fueled Ship (PTS) and Ship to LNG Fueled Ship (STS) as in Figure 2.

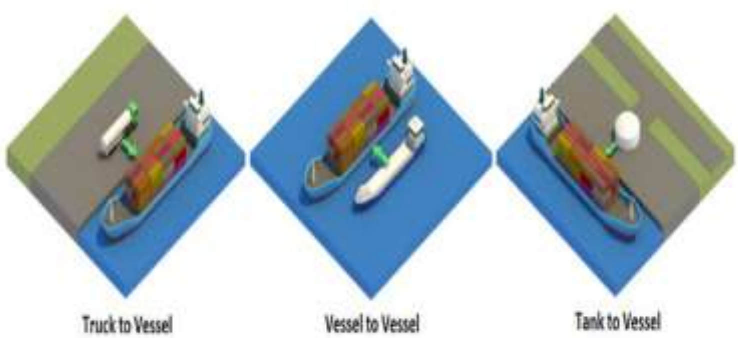

Fig 2: LNG Bunkering Options
Source: Adapted from World LPG Association(2019)

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LNG bunkering can entail either constructing an on-site LNG liquefaction terminal or transferring LNG from an off-site liquefaction facility to a port for temporary storage there on site (https://sgp.fas.org/crs/misc/R45488.pdf.). The financial implication of truck-to-vessel LNG bunkering is minimal skill in operation, although there may be capacity restrictions owing to truck size, restricted roads, or other logistical issues, this method is an effective technique to bunker LNG at lower quantities (https://sgp.fas.org/crs/misc/R45488.pdf.). Furthermore, a port-built storage tank may receive LNG from LNG tanker trucks and use a conduit to bunker the gas for incoming ships. Presently, vessel-to-vessel bunkering with high-sulfur gasoline is the most common technique, carried out by smaller tankers or tank barges.

MATERIALS AND METHODS

The paper is a quantitative review of secondary data acquired from the National Inland Waterways Authority, Nigeria Maritime and Safety Agency, and Nigeria Port Authority, published journals, newspapers, and other sources of data. An inductive research method is used in other to compare and ascertain the present port operations capacity in Nigeria and possible ports to be used for LNG bunkering ports for both ocean-going vessels and coastal operation vessels in Nigeria.

RESULTS AND DISCUSSION

Ocean-Going Vessel Traffic: Nigeria's seaport ocean-going vessel traffic between the period of 2012 – 2017 is indicated in Figure 3 showing the vessel traffic in the six major ports in Nigeria with the ports in Lagos (Apapa and Tin Can Island) recording the highest vessel traffic followed by ports in Port harcourt (Rivers and Onne) and Warri port with Calabar port recording the lowest vessel traffic.

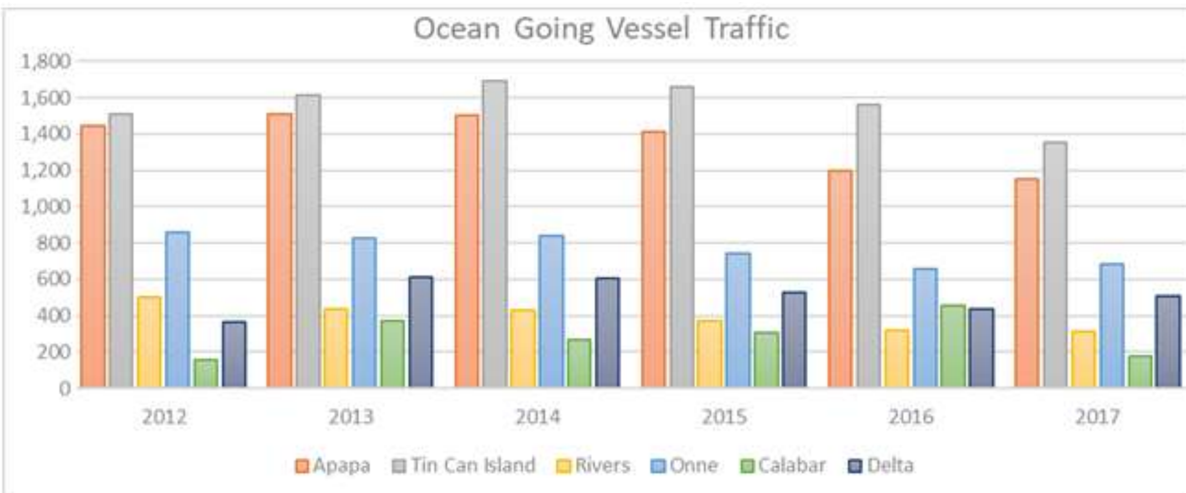

Fig 3: Bar chart of Nigeria Seaports Vessel Traffic (2012 – 2017).
Source: Prepared by Authors, adopted from (https://nigerianstat.gov.ng/elibrary/read/735)

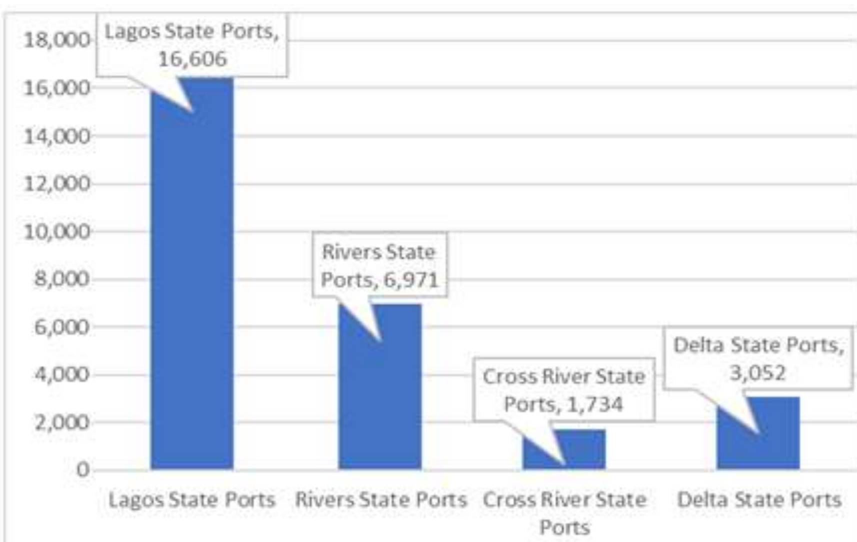

Fig 4: Bar chart of Ocean- Going Vessel Traffic by State where the Port is Located in Nigeria.
Source: Prepared by Authors adopted from (https://nigerianstat.gov.ng/elibrary/read/735)

Figure 4 shows the combination of ports operating in a particular state to make up the total vessel traffic in the port operating state. Ports located in Lagos state have the highest amount of ocean-going vessel traffic, followed by ports located in River state, Delta state, and Cross River state which have the lowest amount of ocean vessel traffic. With Ports in Lagos state having the highest amount of Ocean-Going vessel traffic, citing LNG bunkering infrastructure in any of the ports in Lagos, especially Lekki Seaport will be a fruitful venture considering Lagos state is Nigeria's seaport gateway to other countries in the Gulf of Guinea.

For Service Boat Traffic in the Nigeria Inland Waters: Delta Port has the highest amount of coastal service vessel traffic followed by Onne and Calabar ports. The last port with coastal service vessel traffic is Apapa port followed by Rivers (Port Harcourt) port.

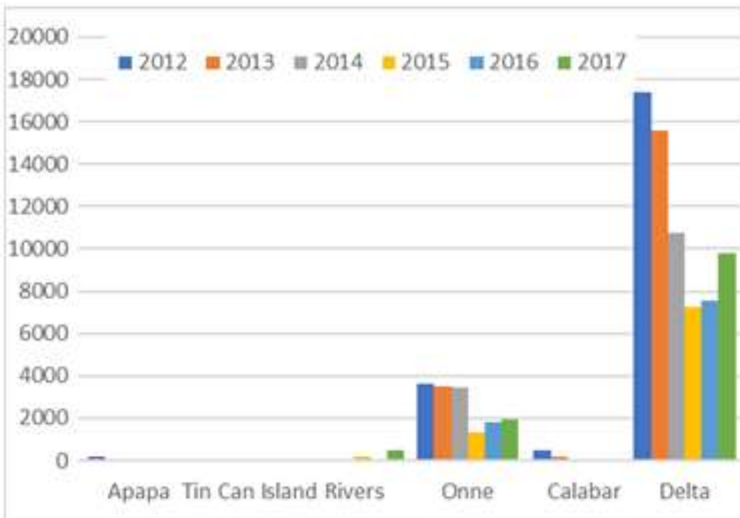

Fig 5: Bar Chart of Coastal Service Vessel Traffic in Nigeria Port
Source: Prepared by Authors, adapted from (https://nigerianstat.gov.ng/elibrary/read/735)

Conclusion: LNG bunkering facilities can be cited in three states with seaports. Lagos state to serve as LNG bunkering hub for the Gulf of Guinea and to be located at Lekki Deep seaport to fuel big LNG vessels big ocean vessels. Delta and Rivers ports will require LNG bunkering facilities to serve both ocean-going vessels and coastal service vessels because of the coastal oil and gas production operations in Nigeria's coastal waters. Nigeria having an LNG bunkering facility will help in the energy transition programme of IMO for the sustainability of the environment and it will encourage most vessels operating in Nigeria's Coastal waters to go for vessel fuel conversion to LNG. Considering the availability of LNG in Nigeria, most vessel operating companies will increase their revenue as they minimize operations costs as a result of Gas Oil to a clean energy and cost-effective LNG fuel.

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