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(Research Article)

# Comparative study of alternative marine power (cold ironing) application as an air pollution mitigation technology in Nigeria seaports

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## Abstract

An amendment to Annex VI of the protocol of 1997 to amend the international convention for the prevention of pollution from ships was adopted by the International Maritime Organization in October, 2018. Annex VI regulations provides regulations for the prevention of air pollutions from ships, to comply with this requirement, Alternative Marine Power or shore base marine power is seen as an attractive option. Ship owners and other stakeholders in the shipping industry are worried with this development especially combining the cost of diesel and electricity and initial cost of cold ironing project. This study therefore is on comparative study of shore base marine power application as an air pollution mitigation technology in Nigeria seaports. Research objectives and hypotheses were formulated, data were sources from many sources and analyzed. The results of the analysis indicated available air mitigation technology for vessels, it also showed that the cost of cold ironing in Nigeria seaport when compared with the cost of electricity in other countries is significant; recommendations were made based on the results and findings.

**Keywords:** Pollution; Mitigation, Technology; Marine Power; Seaport

## 1 Introduction

Nitrogen Oxide (NOx) and Sulphur Oxide (SOx) emissions are contributions from global ship. Statistically, $NO_x$ contributes 13% while $SO_x$ 12% globally, [7]. In 2012, 2.2% greenhouse gas (GHG) emissions of anthropogenic carbon dioxide ($CO_2$) emissions from global shipping were estimated by IMO. In addition, burning of the Sulphur content of marine fuels during shipping contributes to air pollution with SOx and particulate matter as major pollutants , [2].

Residual oil is the least refined petroleum fuel mostly used by ocean-going vessels. It is a byproduct of the refinery process; hence it is dirtier when compared to other refined petroleum products [6], [11]; consequently, during loading of goods, discharging of cargo, passenger boarding and disembarking, on-board electricity is been generated by vessels in ports through running of their engines. Due to the relative low cost of this fuel (residual oil) shipping companies make use of them. On the other hand, air pollution regulations such as pollutions from ship and port-related transport modes as well as the cargo handling equipments are not as rigorous as land-based polluters in a lot of countries, [1].

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Seaports all over the world are main focal points of activities as well as main sources of pollution. There are massive ships with engines operating on the dirtiest fuel and a daily visit of thousands of diesel truck, diesel locomotives of many miles hauling cargo and other polluting equipment, and activities at marine ports contributing to a lot of environmental impacts that can dangerously affect local communities as well as the environment, [3].

Emissions in ports are contributed by vessels, harbour-craft activities, cargo handling equipments, locomotives and trucks for cargo transfer and storage operations, since approximately all engines used in these activities are diesel-fuelled [12].

CORBETT and KOEHLER [5] initially produced worldwide emission record for ocean going vessels and found that ocean-going vessels are main contributors to international emissions of nitrogen and sulphur, and, to a smaller amount, to global emissions of $CO_2$, PM, hydrocarbons (HCs), and CO. CORBETT and KOEHLER [5] persisted that about 80 percent of the international fleet is either harbored (55 percent of the time) or near a coast (25 percent of the time). This shows about 20 percent of the time at sea and about 80% on land by ships. This means that the local air quality would be influence as well as the nearby soil, rivers and lakes due emissions within the coastal and harbour areas.

Options for emission control for Vessels, Locomotives and Cargo Handling Equipments (CHEs) can be categorized in three major strategies. They include technological improvements, operational changes and market based programs. Technology improvements reduce both local and worldwide emissions through replacement or upgrade of old, inefficient or more polluting engines with better efficient and lower-emitting propulsion systems.

Cold ironing (CI) or alternative marine power (AMP) is a technological improvement strategy to reduce both local and worldwide emissions. UNCTAD (13) disclosed the merits of having the CI facility in port, such as the reduction of NOx, SOx and PM emissions, ship operating personnel time reduction in operating power equipments for other works, having extra time for inspection and little repairs and reduction of noise levels on and close to the ship. He also provided the demerit of CI as safety of operation in connecting and disconnecting ships from shore power port and on ship, and as well as the long lead times to engineering and retrofitting power lines, substations and ships. Though quality and environmental advocates continue to strongly mount pressure for the use of CI, shipping companies and ship owners less enthusiasm to respond is due to the cost associated to having both diesel and electric capabilities. To this end, this research looks at the comparative study of shore base marine power application as an air pollution mitigation technology in Nigeria seaports.

### 1.1 Objectives

- To ascertain the air pollution reduction strategies available in Nigeria seaports with respect to the global standard.
- To analyse the cost nature of application of alternative marine power (cold ironing) technology in Nigerian seaports.

### 1.2 Research Questions

- What is the extent of availability of air pollution reduction strategies in Nigeria seaports with respect to the global standard?
- What is the cost nature of application of alternative marine power (cold ironing) technology in Nigerian seaports?

### 1.3 Research Hypotheses

- $H_{01}$: The extent of availability of air pollution reduction strategies in Nigeria seaports with respect to the global standard is not significant.
- $H_{02}$: The cost nature of alternative marine power (cold ironing) technology application in Nigerian seaports is not positive.

## 2 Methodology

This research involved qualitative and quantitative research; primary and secondary data were used in the study. A checklist of air pollution mitigation technology was developed and was used to find out the extent of availability of air pollution mitigation technologies in Nigeria seaport. Secondary data were sourced from various country websites to determine the relative cost of commercial electricity.

## 3 Results

Research Question 1: What is the extent of availability of air pollution reduction strategies in Nigeria seaports with respect to the global standard?

**Table 1** Checklist of air pollution mitigation technologies/ strategies in Nigerian seaports

| S/N | Pollution mitigation availability (IMO requirement) | APAPA seaport | Tincan seaport | Warri seaport | Onne seaport | Port Harcourt seaport |
|---|---|---|---|---|---|---|
| 1 | Use a compliant fuel oil with a sulphur content fuel that does not exceed 0.50% in vessels | Available | Available | Available | Available | Available |
| 2 | Use a compliant fuel oil with a sulphur content fuel that does not exceed 0.50% on locomotives and CHEs | Not available | Not available | Not available | Not available | Not available |
| 3 | Availability of electric motor technology | Available | Available | Available | Available | Available |
| 4 | Exhaust Gas Recirculation for NOx reduction | Available | Available | Available | Available | Available |
| 5 | Vessel engine Repower and retrofit | Few vessels | Few vessels | Few vessels | Few vessels | Few vessels |
| 6 | If exceeding 0.50%, use an equivalent e.g., an Exhaust Gas Cleaning System ("Scrubber") on vessels | Not available | Not available | Not available | Not available | Not available |
| 7 | Use onshore power supply when at berth | Not available | Not available | Not available | Not available | Not available |
| 8 | Use an alternative fuel e.g. LNG, methanol (SOx target) | Fairly available | Fairly available | Fairly available | Fairly available | Fairly available |
| 9 | Use of regulations/ legislation (all pollutant targeted) | YES | YES | YES | YES | YES |
| 10 | in-water cleaning policy (inversive speies targeted) | NO | NO | NO | NO | NO |
| 11 | Use of Biofuels | NO | NO | NO | NO | No |
| 12 | Batteries vessels (NOx, SOx, PM, Cox etc targeted) | Fairly available | Fairly available | Fairly available | Fairly available | Fairly available |
| 13 | Market base instrument (SOx and Cox targeted) | NO | NO | NO | NO | NO |
| 14 | Air Quality Monitoring | YES | YES | YES | YES | YES |
| 15 | Air Quality Implementation | YES | YES | YES | YES | YES |

Source: 2021 research survey

From table 1, shows a checklist with 15-items. For the use of a compliant fuel oil with a sulphur content fuel that does not exceed 0.50% in vessels in Nigeria seaports, the checklist indicated that Nigeria seaports under study has ensured application of low sulphur compliant fuel for vessels entering the port. For the use of a compliant fuel oil with a sulphur content fuel that does not exceed 0.50% on locomotives and CHEs, the checklist indicated that Nigeria seaports under study has not adopted the application of low sulphur compliant fuel for locomotives and Cargo handling equipments. From the checklist, all the Nigeria seaports recorded availability of electric motor technology item.

The checklist also recorded availability of Exhaust Gas Recirculation for NOx reduction by most vessels calling in the Nigerian seaports. It also shows that there are available air quality monitoring and implementation programs by the Nigeria Ports Authority. The checklist indicated fair availability of alternative fuel such as LNG, methanol to reduce SOx from vessels, Batteries usage for vessels to reduce NOx, SOx, PM, COx, vessel repowering and retrofitting technology.

On the other hand, the checklist shows absence of the following air mitigation technologies in Nigeria seaports: biofuels, in-water cleaning policy (invasive species targeted), Market base instrument (SOx and Cox targeted), alternative marine power or cold ironing (use of offshore supply power when at berth.

From the above checklist, it is obvious that there is availability of air pollution mitigation technologies in Nigeria seaport, though which cannot be said to be significant considering other sources of pollution in Nigeria seaports like CHEs and locomotives that have no mitigation technologies.

### 3.1 Comparative analysis of cold ironing project in Nigeria seaports with respect to other world ports

**Table 2** Electricity tariffs at bunkering locations

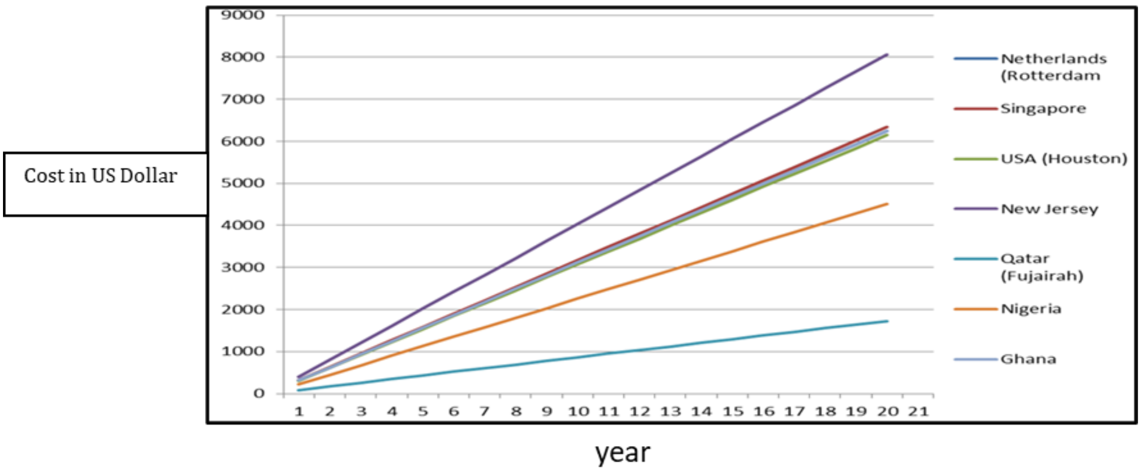
| | Country | Cost/kW-hr ($) |
|---|---|---|
| 1 | Netherlands (Rotterdam) | 0.130 |
| 2 | Singapore | 0.132 |
| 3 | USA (Houston) | 0.128 |
| 4 | New Jersey | 0.168 |
| 5 | Qatar (Fujairah) | 0.036 |
| 6 | Nigeria | 0.094 |
| 7 | Ghana | 0.130 |

Source: Compiled from the respective country websites

From table above, Fujairah and Nigeria has the lowest tariff with New Jersey having the highest tariff among the seven (7).

### 3.2 Cost of electricity/day based on ship power requirements

The cost of using shore power in the respective countries of the bunkering locations was determined based on the auxiliary power requirements of ships and the electricity tariffs.

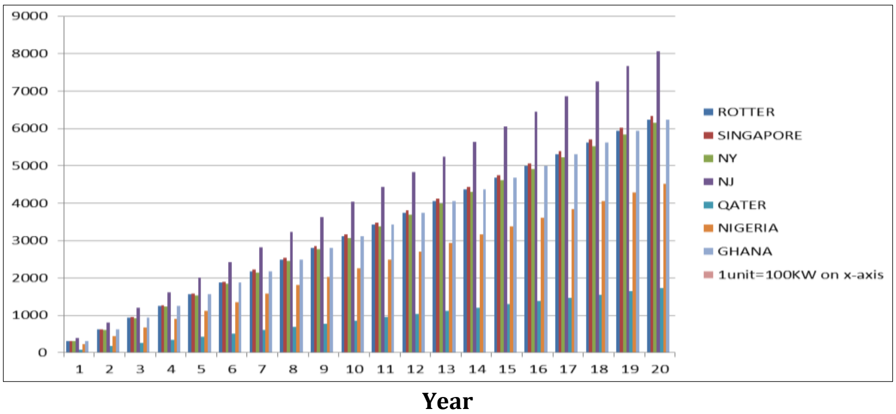



Source: Researcher's computation

**Figure 1** Figure representing cost of cold ironing in Nigeria and some global ports

**Table 3** Cost of electricity/day ($) based on ship power requirements

| | Power requirement (KW) | Netherlands (Rotterdam) | Singapore | USA (Houston) | New Jersey | Qatar (Fujairah) | Nigeria | Ghana |
|---|---|---|---|---|---|---|---|---|
| 1 | 100 | 312 | 316.8 | 307.2 | 403.2 | 86.4 | 225.6 | 312 |
| 2 | 200 | 624 | 633.6 | 614.4 | 806.4 | 172.8 | 451.2 | 624 |
| 3 | 300 | 936 | 950.4 | 921.6 | 1209.6 | 259.2 | 676.8 | 936 |
| 4 | 400 | 1248 | 1267.2 | 1228.8 | 1612.8 | 345.6 | 902.4 | 1248 |
| 5 | 500 | 1560 | 1584.0 | 1536.0 | 2016.0 | 432.0 | 1128.0 | 1560 |
| 6 | 600 | 1872 | 1900.8 | 1843.2 | 2419.2 | 518.4 | 1353.6 | 1872 |
| 7 | 700 | 2184 | 2217.6 | 2150.4 | 2822.4 | 604.8 | 1579.2 | 2184 |
| 8 | 800 | 2496 | 2534.4 | 2457.6 | 3225.6 | 691.2 | 1804.8 | 2496 |
| 9 | 900 | 2808 | 2851.2 | 2764.8 | 3628.8 | 777.6 | 2030.4 | 2808 |
| 10 | 1000 | 3120 | 3168.0 | 3072.0 | 4032.0 | 864.0 | 2256.0 | 3120 |
| 11 | 1100 | 3432 | 3484.8 | 3379.2 | 4435.2 | 950.4 | 2481.6 | 3432 |
| 12 | 1200 | 3744 | 3801.6 | 3686.4 | 4838.4 | 1036.8 | 2707.2 | 3744 |
| 13 | 1300 | 4056 | 4118.4 | 3993.6 | 5241.6 | 1123.2 | 2932.8 | 4056 |
| 14 | 1400 | 4368 | 4435.2 | 4300.8 | 5644.8 | 1209.6 | 3158.4 | 4368 |
| 15 | 1500 | 4680 | 4752.0 | 4608.0 | 6048.0 | 1296.0 | 3384.0 | 4680 |
| 16 | 1600 | 4992 | 5068.8 | 4915.2 | 6451.2 | 1382.4 | 3609.6 | 4992 |
| 17 | 1700 | 5304 | 5385.6 | 5222.4 | 6854.4 | 1468.8 | 3835.2 | 5304 |
| 18 | 1800 | 5616 | 5702.4 | 5529.6 | 7257.6 | 1555.2 | 4060.8 | 5616 |
| 19 | 1900 | 5928 | 6019.2 | 5836.8 | 7660.8 | 1641.6 | 4286.4 | 5928 |
| 20 | 2000 | 6240 | 6336.0 | 6144.0 | 8064.0 | 1728.0 | 4512.0 | 6240 |




Source: Researcher's computation

**Figure 2** Bar chart representing the ship power requirements for each country

For a ship with an auxiliary engine power requirement of 600 kW in berth, it will cost per day approximately $518.4, $1353, $1843, $1872, $1900 and $2419 for Fujairah, Nigeria, Houston, Ghana, Rotterdam, New Jersey and Singapore respectively.

For a ship with an auxiliary engine power of 1000 kW in berth, it will cost per day approximately $864, $2,256, $3,072, $3,120 and $4032 for Fujairah, Nigeria, Houston, Ghana, Rotterdam, New Jersey and Singapore respectively.

For a ship with an auxiliary engine power requirement of 2000 kW in berth, it will cost per day approximately $4,512, $1,728, $6,144, $6240, $6,240, $6336 and $8,064 for Fujairah, Nigeria, Houston, Ghana, Rotterdam, New Jersey and Singapore respectively.

### 3.3 Test of Hypothesis one ($H_{01}$): The extent of availability of air pollution mitigation technologies in Nigeria seaports with respect to the global standard is not significant

Table 1 indicated that Nigeria seaports' air pollution mitigation technology availability are recorded for vessels only, there were no significant availability of mitigation technology for CHEs and locomotives with respect to the global standard since emission from these sources impact on the environment severely. The researchers therefore accept the null hypothesis and conclude that the extent of availability of air pollution mitigation technologies in Nigeria seaports with respect to the global standard is not significant.

### 3.4 Test of hypothesis two ($H_{02}$): The cost nature of alternative marine power (cold ironing) technology application in Nigerian seaports is not positive compare to world ports

Analysing the difference in cost per day for ships using CI in ports in Fujairah and Nigeria, the cost of using shore electricity to power ships at berth proved very positive thereby recording lower costs compared to ships using shore electricity in other world ports and African ports in Ghana.

The researchers therefore reject the null hypothesis and concluded that the nature of cost of alternative marine power (cold ironing) technology application in Nigerian seaports is positive.

## 4 Discussion

Hypothesis ($H_{01}$) showed that the extent of availability of air pollution reduction strategies in Nigeria seaports with respect to the global standard is not significant. This is evident in our seaports are there are no substantial mitigation technologies like cold ironing or shore power for alternative marine power to ships at berth. Also CHE, locomotives and trucks runs on traditional marine fuel instead of a cleaner marine fuel like LNG, biofuel and the use of batteries by this equipment. This area of research serve as a contribution to knowledge as there was no previous research in this area.

Hypothesis ($H_{02}$) showed that **t**he cost nature of alternative marine power (cold ironing) technology application in Nigerian seaports when compared to world ports is positive. From the analysis, it is evident that cold ironing investment in Nigerian seaport is highly promising when compared to the global port of Rotherderm, New York, New Jersey or European and Asian port in general. The initial investment cost, earning per annum and operating cost per annum could impact on the overall NPV (Net present Value) and Internal Rate of Return (IRR) on investment per vessel or operators while using the CI facility in the short and medium terms, but return on investment is certain and promising when compared to global ports. Also reduction in electricity taxes and use of incentives could help yield better result as the ports in Nigeria will compete favorably with global ports to remain green. This research is consistent with the research of [10], [8] and [9] whose study showed that CI is only technically feasible for installation in most ports, hence a pointer to the fact that ports cannot in any way on their own bear the full financing of the CI facility. According to him, CI can become economically viable if the State puts in place a tax exemption package for ships using shore power in ports to serve as an incentive for ship operators to switch over to using CI or when the prices of marine fuels go up so high as to make it uneconomical compared to using CI.

Technologically, the study observed that the environmental benefits associated with CI in the reduction of NOx, SOx and PM is substantial as it eliminates or considerably reduces all these pollutant emissions in shutting down of the ship's auxiliary engine. Compared to the other emission reduction techniques, CI also eliminates completely the noise that is commonly associated with ship hotelling. It was observed that the technique of repowering with natural gas/duel fuel engine, the use of SCR system in combination with low sulphur fuels (MGO) has the potential to serve as a very good alternative to CI. The study noted that Nigeria stands a better chance in adopting CI technique in terms of cost and benefits associated with the technology when compared with other African countries and global ports of Asia, Europe and USA.

## 5 Conclusion

This study has made valuable contributions in informing that Nigeria seaports stand a better chance on Return on Investment (ROI) of adopting Alternative Marine Power (AMP) considering her daily cost of commercial electricity when compared to the countries of USA, Europe, and Asia who have adopted the AMP practice as well as African countries like South Africa and Ghana.

However, the study was able to reveal air pollution mitigation challenges peculiar to the Nigerian seaports, these obvious challenging factors which include technical-know-how, maintenance culture, fuel cost, retrofitting challenge, scrubber challenge and bunkering infrastructural challenge Factors are not peculiar to Nigeria alone, however through recommendation the research contributed that good tax policy system could go a long way to ameliorate the cost impact of these challenging factors.

### *Recommendations*

- There is absolute need for Nigerian Ports to give incentives to 'green' ships to encourage them to invest in other effective port-based emission reduction techniques.
- There should be an urgent call for Nigerian Ports to invest in AMP as a competitive tool whereby AMP ships could be granted priority to use terminals any time they arrive by so doing afford AMP ships a competitive advantage.
- Nigerian seaports with good hinterland connections that serve as a key import/export centre for goods transported in the region could exploit their advantageous position in discussing with shipping companies the implementation of CI.
- Government and other stakeholders must join forces in financing the air pollution mitigation technologies in Nigeria.

## Compliance with ethical standards

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### *Disclosure of conflict of interest*

Authors declare that there is no conflict of interest in the paper.

## References

[1] Adams M, Quinonez P, Pallis A, Wakeman T. Environmental Issues in Port Competitiveness, Center for International Trade and Transportation Working Paper 7, Dalhouse University. 2010.

[2] Anyanwu JO. Espousing Liquefied Natural Gas as Marine Propulsion Fuel: LAP LAMBERT Academic Publishing (2017-07-25 . 2017; SBN-13: 978-3-659-63957-9,

[3] Badejo B, Solaja MO. Dilemma of Indigenous Shipping Industry in Nigeria: A Reflection, Journal of Engineering and Environmental Studies. 2014; 5(1): 123-131

[4] Bailey D, Plenys T, Feuer GR, Solomon Bella T, Julie MGM, Campbell TR. Harboring Pollution: Strategies to clean US Ports. NRDC, the Earth's Best Defense. 2004.

[5] CORBETT JJ, KOEHLER H. Updated Emissions from Ocean Shipping", Journal of Geophysical Research. 2003; 108.

[6] Han CH. Air Pollution Reduction Strategies of World Major Ports. The International Commerce and Law Review. 48 Dec 2010

[7] IPCC. Climate change: Synthesis report. Contribution of working groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pachauri, R. K. & Reisinger, A. (Eds.). Geneva, Switzerland: IPCC. 2007.

[8] Jerzy H. LNG as a marine fuel – Possibilities and Problems. Journal of KONES Power train and Transport, Vol. 18, No. 2 2011. Gdynia Maritime University Marine Power Plant Department Morska Street 81-87, 81-225 Gdynia, Poland JesperAagesen, Senior Surveyor, Ship Design Specialist, Lloyd's Register, Denmark). 2011.

[9] Man Diesel and Turbo. The Cost and Benefit of LNG as marine fuel for container vessels. 2012.

[10] Meyer, Michael D. Marine transportation and the environment. Department of Civil Engineering, Georgia Institute of Technology, Atlanta, Georgia. Mc Graw Hill, Access Science. 2010.

[11] Mohseni SA, Hassel CEV, hrista Sys, Thierry Vanelslander. Economic evaluation of alternative technologies to mitigate Sulphur emissions in maritime container transport from both the vessel owner and shipper perspective. Journal of Shipping and Trade. 2019.

[12] Walker TR, Adebambo O, Del Aguila Feijoo MC, Elhaimer E, Hossain T, Edwards SJ, Morrison CE, Romo J, Sharma N, Taylor S, Zomorodi S. Environmental Effects of Marine Transportation. World Seas: An Environmental Evaluation. 2019; 505–530.

[13] UNCTAD. Review of Maritime Transport. 2019.