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Onshore power for the docked container vessels in Apapa Port through blended finance

Oladayo Matthew Atilola

ONSHORE POWER FOR THE DOCKED CONTAINER VESSELS IN APAPA PORT THROUGH BLENDED FINANCE

SUB-TITLE

ATILOLA OLADAYO MATTHEW

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of Master of Science in Maritime Affairs

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): ....

(Date): ....

Supervised by: ....

Supervisor’s affiliation: ....

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Abstract

Title of Dissertation: **Onshore Power for the Docked Container Vessels in Apapa Port Through Blended Finance.**
Degree: **Master of Science**

The dissertation is a study of Onshore Power for the Docked Container Vessels in Apapa Port Through Blended Finance**.**

In the contemporary maritime landscape of Nigeria, the challenges faced by container vessels docked at the Lagos Port system, especially the Apapa port, necessitate comprehensive scrutiny. This investigation pivots around the implementation of Onshore Power Supply (OPS) as a potent remedy, emphasizing its myriad advantages. To methodologically ascertain these, the study pursued three primary objectives: delineating the inherent challenges confronted by stationary vessels in Lagos, extrapolating the prospective benefits of integrating OPS into this maritime nexus, and probing the viability of employing a Blended Finance paradigm for facilitating OPS installation. To rigorously analyse these dimensions, sophisticated analytical tools were employed, encompassing the OPS calculator, Monte Carlo simulations via Crystal Ball, and advanced financial modelling techniques, including Net Present Value (NPV) and Internal Rate of Return (IRR) estimations executed within Excel. The empirical findings corroborate the prospective efficacy of OPS within the Nigerian context, particularly due to the juxtaposition of the nation's economic electricity tariffs and the pronounced social ramifications of maritime emissions. Conclusively, the data suggests that Nigeria's maritime infrastructure is primed for the integration of OPS. This transition promises not only enhanced public health outcomes but also a substantial alignment with global decarbonization imperatives. Moreover, the economic viability remains robust even at electricity tariffs of €0.23 per kW—a figure markedly more economical than the prevailing costs of marine diesel oil, the predominant fuel for vessels at berth.

KEYWORDS: Greenhouse gases,OPS,NPV,SWOT,Emissions

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List of Abbreviations

AATIF	Africa Agriculture and Trade Investment Fund
AMP	Alternative Maritime Power
CCD	Copernicus Climate Data
CH4	Methane
CO2	Carbon dioxide
COP	Conference of Parties
DAC	Development Assistance Committee
DFI	Development Financial Institutions
EDDI	Energy Efficiency Design Index
ESG	Economic Social and Governance
GHG	Greenhouse gas
GMN	Global Maritime Network
IEA	International Energy Agency
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LNG	Liquefied Natural Gas
MDBs	Multilateral Development Banks
MEM	Maritime Energy Management
MTCC	Maritime Technology Corporation Centre
NIMASA	Nigerian Maritime Administration and Safety Agency
NOx	Nitrogen oxides
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
OPS	Onshore Power Supply
PM	Particulate Matter
SDGs	Sustainable Development Goals
Sox	Sulfur oxides
UN	United Nations
IRR	Internal Rate of Return
PBP	Pay Back Period

1.0 Chapter 1: Introduction

1.1 Background

International maritime shipping is an essential part of the Global freight transportation system, which is not limited to shipping but includes ocean, coastal routes, inland waterways, road networks, railway networks and air freight and more recently pipelines (Gallagher, 2010).

Shipping is responsible for the development of trade over the years as its direct connection to trade growth has been established (Estevadeordal et al., 2003).

According to data from commerce trade of the United Nations (Download AIS Data | UN Comtrade: International Trade Statistics, n.d.), container shipping was responsible for moving 16,430,915,053.16 metric tons in the year 2022, this encompasses both imports and exports. Maritime shipping has helped reduced what the natural cost of products could have been when proximity to raw material and manufactured product is considered.

1.2 Global Shipping and Climate Change Impact on Africa.

There has been a clamour for the need to mitigate the effect of climate change, and Africa isn't left aside in this conversation. Shipping as a human activity is responsible for over 3.9% of anthropogenic greenhouse gas emission (Budiyanto et al., 2022) and it would have been labeled as the 6th largest emitter if shipping were a nation.

The Intergovernmental Panel on Climate Change (IPCC) have projected that temperatures in Africa would increase by more than the global average, with an upward increase of 3.9 °C by the end of the century and this would negatively impact on Africa and give rise to intense heatwaves, flooding, droughts while also creating a cascading effect on coastal erosions and rising sea level and even sea surface temperature that would affect fishing negatively (Ayesu & Asaana, n.d.).

The welfare of African nations has improved overtime through trade, but policies should be designed to reduce carbon emissions or mitigate climate change effects in order to promote sustainable economic development in Africa (Ayesu & Asaana, n.d.).

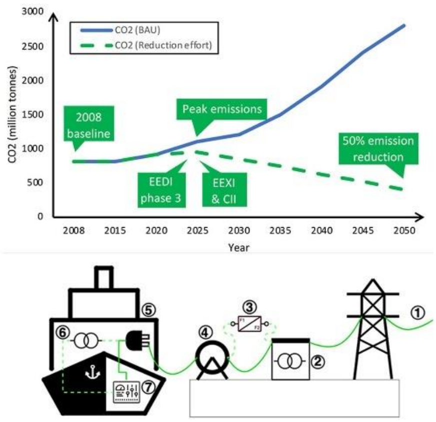
1.3 Shorepower and Maritime Decarbonization

In the light of the IMO ghg strategy and the conscious efforts of the United Nations to reduce ghg emissions, it has become imperative for the maritime industry to innovate ways to achieve the goal. Shorepower becomes a low hanging fruit in achieving this as it reduces the emissions in port areas. Shorepower can eliminate emissions by a 100% while ships are at berth as ships would be plugged to the power from alternative source while at berth.

Recent regulations support EU's Green Deal & Fit for 55 goals. Starting 2025, maritime ports must provide shore power for 90% of vessel needs. Inland waterway ports in TEN-T core areas need shore electricity installations from 2025. On October 14, 2021, the European Commission proposed a new regulation to replace Directive 2014/94/EU due to its lack of a comprehensive methodology for member states. This led to inconsistent and insufficient plans not aligned with EU targets. The original directive aimed to establish a common framework for alternative fuels infrastructure, reducing oil dependency and transport sector emissions by 25%. Shore-to-ship power, a vital alternative fuel technology, allows vessels to use shore electricity instead of onboard diesel generators during berthing. This technology has gained traction in EU ports since its introduction in 2000, with initiatives in Spanish, French, and Baltic Sea ports.

The Sulphur Directive pertains to the regulatory measures enacted by the European Union with the aim of restricting the concentration of sulphur in specific types of fuels, primarily those utilised in maritime applications. The primary objective of these instructions is to mitigate the release of sulphur emissions originating from maritime vessels, as they have been identified as a significant contributor to air pollution and subsequent environmental degradation. One prominent regulation in this particular sphere is to the MARPOL Annex VI, which establishes worldwide benchmarks for the sulphur concentration in maritime fuels and is overseen by the International Maritime Organisation (IMO). The Sulphur Directive assumes a vital role in facilitating the advancement of cleaner and more ecologically sustainable maritime transportation.

Figure 1: Imo ghg emission target and graphical representation of OPS



Source: (Daniel et al., 2022)

Shore power can remove greenhouse gas (GHG) and air pollution emissions at ports immediately and internationally, it improves ship efficiency globally, and it serves as a catalyst for the development of new maritime applications like hybridization and electrification (Daniel et al., 2022).

The relationship between ports and OPS is further accentuated by rising global environmental awareness. As regulatory bodies apply pressure on ports to diminish their carbon footprint, adopting practices like OPS can position ports as sustainability leaders. However, the implementation demands both the port and the ships to have compatible infrastructure. This involves investments in technology and infrastructure by the ports. In turn, such eco-friendly initiatives can boost a port's reputation, possibly attracting more shipping lines that prioritize environmental responsibility. In essence, the nexus between ports and OPS represents a symbiotic blend of environmental responsibility and operational efficiency.

The environmental repercussions of global emissions on coastal regions cannot be overstated. It is important to note that an estimated substantial 70% of these emissions have their origins within an area that spans a 400 km radius from ports around the world (Canepa et al., 2023). This concentrated occurrence of emissions paints a stark picture of the environmental impact on these coastal regions. Consequently, the undeniable link between port activities and the environmental health of surrounding areas is brought into clear focus, emphasizing the need for proactive measures to mitigate these effects.

Ports are central to maritime operations, serving as the nodes that link sea and land-based logistics. The energy demands of ports are substantial, given the need to power a variety of activities like loading/unloading cargo, lighting, refrigeration, and running administrative buildings. Moreover, when ships are docked, they often rely on auxiliary engines for power, leading to further energy consumption and emissions.

With the shift towards greener and more sustainable operations, ports around the world are seeking ways to optimize their energy use. This includes strategies like OPS, where docked ships can turn off their auxiliary engines and receive power from the shore, leading to lower emissions and energy costs. The progression towards green and smart ports necessitates adaptive governmental oversight and regulation in line with evolving phases (Meng et al., 2020).

The OPS technology is relatively new and as such very costly for developing nations such as Nigeria, hence the need for technical financial structure for ownership. While a lot of strategic ways have been recommended to improve Nigeria's system of seaport operations, there is no gainsaying that government funding alone has proven overtime to be insufficient. Thus, Blended finance as a strategic use of development finance for the mobilization of additional finance towards sustainable development in developing countries like Nigeria, seem to be a dependable alternative to raise financial support to augment activities of seaports in Nigeria. According to the United Nations (UN) blended finance is “combining concessional public finance with non-concessional private finance and expertise from the public and private sector”. In the similar vein, The Organization for Economic Co-operation and Development (OECD) Development Assistance Committee (DAC)’s defined blended finance as the strategic use of development finance for the mobilization of additional finance towards the SDGs in developing countries. On the other hand, the Development Financial Institutions (DFI) Working Group defines blended finance as “combining concessional finance from donors or third parties alongside DFIs’ normal own-account finance and/or commercial finance from other investors, to develop private-sector markets, address the SDGs, and mobilize private resources. (International Development Finance Club 2019). An example of a blended finance facility using a ‘cascade’ approach is the Africa Agriculture and Trade Investment Fund (AATIF). This facility according to Development Co-Operation Directorate (2017) provided the USD172 million public-private structure debt fund which was administered by Deutsche Bank and targets sustainable agriculture investments in Africa.

1.4 Problem Statement.

Nigeria seems to be lagging in the deployment of the OPS even as seaports across the world have continued to embrace the innovation. According to (Zis, North, Angeloudis, Ochieng, & Bell, 2014), OPS has been implemented in numerous ports such as Los Angeles, Antwerp, Genoa, Gothenburg, and Oslo, as a measure to reduce emissions and noise from ships. The major problem that motivates this research is the seeming inefficiencies in the port operations that has led to increased port time for ships due to delays. This also cost the nation a lot more resources and time because OPS as an alternative has not been adopted in most developing countries' ports, despite emissions from port operations causes health-related issues to the surrounding communities.

Currently, docked container vessels at the Apapa Port rely predominantly on their auxiliary engines to power onboard systems, leading to substantial greenhouse gas emissions and air pollutants. Despite the recognized environmental benefits of transitioning to OPS, commonly known as OPS, its adoption is hampered by significant financial and infrastructural barriers.

By maintaining the status quo, the Apapa Port not only continues contributing to local air pollution and the associated health risks for the surrounding communities, but it also positions Nigeria further away from achieving its commitments to reducing greenhouse gas emissions in line with international climate accords.

Sustainable port operations require eco-friendly practices and technologies. Reduce pollution, conserve energy, and protect local ecosystems. For future generations to meet their needs, it prioritizes long-term viability. Clean energy and best practices make ports greener and more profitable. It's about balancing economic growth, environmental protection, and social well-being. This helps nature and worldwide maritime ports. Moreover, failing to adapt to global sustainable port practices could reduce the port's competitiveness on the international stage.

1.5 Motivation

In the face of escalating global climate challenges, sectors across the board are under pressure to curtail greenhouse gas emissions, with the maritime industry emerging as a significant contributor. Notably, international ports are transitioning towards eco-friendlier operations, with technologies like OPS gaining traction.

However, transitioning to OPS, especially in developing regions like Nigeria, isn't devoid of challenges, primarily financial. The substantial costs involved in setting up OPS infrastructure demand innovative financing solutions beyond traditional models. Enter blended finance—a mechanism amalgamating public and private resources, showing promise in various infrastructural contexts in developing economies. For Nigeria, a move towards OPS at the Apapa Port, especially if facilitated by blended finance, not only signals a commitment to local environmental and economic betterment but also fortifies its stance in global sustainability endeavors.

1.6 Aims and objectives.

The overall goal of this study is to dissect how blended finance can be used to fund the implementation of OPS in Nigeria’s port system. Thus, in a bid to achieve this goal, the study will focus on achieving the following objectives;

- Identify and explain challenges of docked container vessels in the Lagos Port system
- Explain the potential benefits of implementing OPS in the Lagos port system
- Discuss how Blended Finance be used to fund the implementation of OPS in the Lagos port system

1.7 Research Questions

- What are the potential benefits of implementing OPS in the Lagos port system?

- What are the challenges of docked container vessels in the Lagos port system?

- How can Blended Finance be used to fund the implementation of OPS in the Lagos port system?

1.8 Research Limitations.

- The study will not delve into other financing mechanisms outside of blended finance.

- The focus will remain on container vessels, not considering other types of vessels docking at Apapa Port.

1.9 Geographical Limits:

- Apapa Port, Lagos, Nigeria.

1.10 Population or Sample Size:

- Container vessels docking at Apapa Port within the stipulated time frame (2022).

1.11 Methodology:

- Data collection through port records, vessel energy demands.

- Financial modeling to ascertain OPS viability and expected returns.

- Environmental impact assessment to gauge potential emission reductions.

1.12 Expected Outcomes:

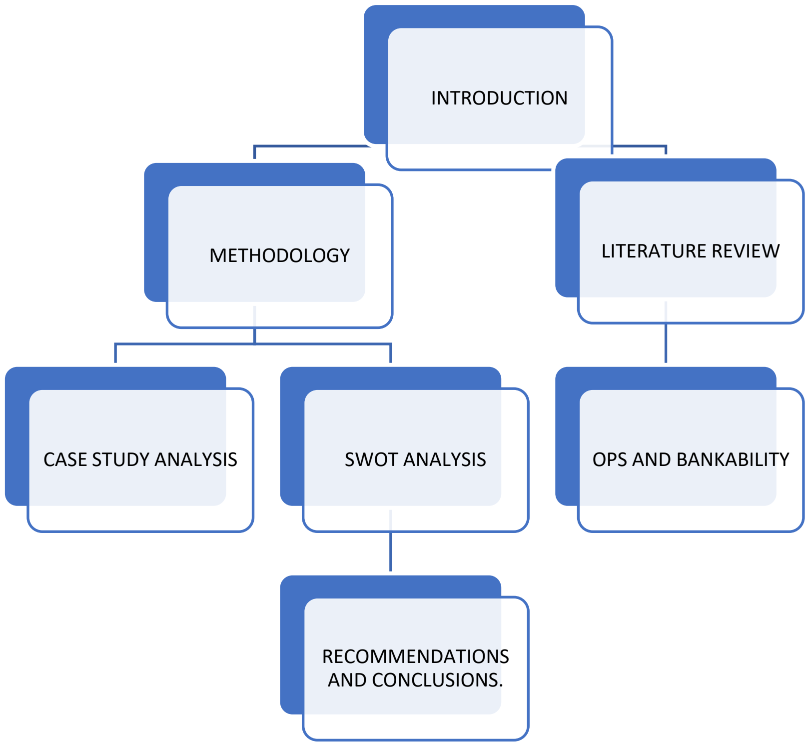
- An estimate of potential emission reductions and operational efficiencies.

- Recommendations for stakeholders and policymakers.

1.13 Relevance & Significance:

- As global emissions regulations tighten and environmental concerns grow, ports like Apapa need sustainable solutions. This research will provide a pathway for integrating green technologies using innovative financial mechanisms.

1.14 FLOWCHART



2.0 Chapter 2: Literature Review

2.1 Chapter Overview

Unprecedented Global warming effects and the other resultant effects of climate change has become the major driver of all United Nations activities in recent times. Climate change and its effects have grown from a catch phrase to a question of Business continuity and a major concern for sustainable living. People have been sacked from their place of abode while having their sustenance or livelihood taken from them without warning.

Threat to business continuity has become an impetus for business owners to strike a balance with the need to also be proactive as it relates to combatting climate change and global warming.

As the world races towards achieving the ambitious target of 1.5 C as stipulated by the United Nations through the various instruments proposed by her Agencies, OPS or shore power is seen at the port level as the first step towards achieving this feat as it has the potential of achieving a 100% carbon reduction from ships at berth (Daniel et al., 2022).

This chapter seeks to conduct a literature review of OPS and how Blended Finance can be used to finance the provision of the infrastructure. There would be a touch up on the Marpol convention as it is designed to combat Ghg emissions and related air quality as it affects International Shipping and how all these externalities have an huge influence on the Decarbonization Agenda of the International Maritime Organization (IMO).

2.2 INTERNATIONAL REGULATIONS

The IMO has been proactive on the issues surrounding Decarbonization. The Paris Agreement predates the Imo ghg strategy. The United Nations Framework Convention on Climate Change (UNFCCC), it was a historic international agreement that addresses climate change. On December 12, 2015, it was adopted, and on November 4, 2016, it came into effect. The major objective of the agreement is to keep global warming far below 2°C, ideally to 1.5°C, in comparison to pre-industrial levels.

However, International shipping was excluded from the paris Agreement because of the peculiar nature of shipping activities. This became an impetus for the IMO to come up with her own Ghg reduction strategy to reduce ghg emissions from international shipping by 50% in 2050 (Joung et al., 2020).

2.3 OPS

Even with obvious derived benefit of using onshore power system as regards to environmental benefits and the accruing benefits from the attendant opportunity cost of not burning fossil fuel in the light of the rising cost of energy and energy security crisis prevalent in the world, adoption of OPS is still very much low compared to what it should have and research suggests that the adopters are faced with various complex barriers. We would be categorizing barriers and drivers for successful implementation of OPS.

Among various technologies that serve as an impetus for sustainable shipping, OPS have been penned down as a low hanging fruit as it viewed as a straightforward process of installing compatible hardware in ports and vessels (Williamsson et al., 2022). In view of this, adoption of OPS might be considered as a no brainer but the barrier of the limited space for hardware installation (Khersonsky et al., 2007) that is a very present limitation of port facility.

Prospective users face significant challenges that are challenging to overcome, including the comparative cost analysis between fuel and electricity, the financial inputs required for hardware, and the presence of under-developed standards and inadequate regulations (Arduino et al., 2011).

A framework is suggested by (Williamsson et al., 2022) and this is divided into barriers and drivers that affects the adoption of OPS. These barriers and drivers are categorized into four major areas;

i. Technology and Operations
ii. Institutional Elements
iii. Economic Elements
iv. Stakeholders Elements

The framework further divides these categories into three areas of concerns; ports, transmission and vessel. Striking a balance between these three areas of concern addresses the technical issues surrounding OPS.

(Tseng & Pilcher, 2015) grouped every concern about implementation of the OPS into four challenges; cost of installation, access to power and connectivity, complexity of designs and safety concern, the obvious lack of binding international and national regulations on air emissions. A further study carried out by (Radwan et al., 2019) identified eleven barriers in five aspects associated with the adoption of OPS in a container port which is the area of this thesis; economic (investment cost, operational and maintenance cost, electricity cost); technical (power requirement, frequency and voltage variation, electrocution risks); managerial (port and ship operator's collaboration, ownership of the facility, sources of funding); regulatory (voluntary character of shore power); and environmental (content of the energy mix). It can be further argued that the energy mix should not be a standalone aspect as the Port may decide to be an energy hub and produce clean renewable energy herself or procure renewable energy from other suppliers, the environmental aspect should be considered as an aspect of technology and operational aspects of the OPS.

2.3.1 Technology and Operations

According to (Arduino et al., 2013), technology and operations is characterised by three components; electrical hardware at the port, components and operational decisions as regards transmission of power safely between interface at the port side and the vessel, and the electrical infrastructure onboard the vessel. Even though there is no single standard as regards how these components are designed, (Innes & Monios, 2018), (Khersonsky et al., 2007) and (Arduino et al., 2011) all agreed that these components may bolster or hinder successful implementation of the OPS. The table shows the components

2.3.2 Port Barriers – Electrical Hardware.

Ports are generally impacted by the limitation of land for infrastructure or development, a case study of the port of Aberdeen showed space required for these electrical components push the limits of what was possible both operational and financially especially in ports that require several OPS units for their small berths (Innes & Monios, 2018).

A possible collaboration by key stakeholders of the port authorities and ship designers would help lower the cost as cost-effective solutions would be arrived at if there was an effective synergy between these actors (Khersonsky et al., 2007). General standards have now been developed for specific compliances especially for safety reasons (Nguyen et al., 2021).

Access to clean and affordable energy is a huge barrier to adoption since the major derived benefit is emission reduction, (Nguyen et al., 2021), (Acciaro et al., 2014), (Iris & Lam, 2021), (Bailey & Solomon, 2004) all agreed that this puts untold pressure on energy management and adoption of smart grid solutions. This has led to genuine interests in alternative fuels for the production of energy at various ports through cogeneration plants, (Colarossi & Principi, 2020) favours using natural gas while (Karimpour et al., 2019) prefers biogas and (Martínez-López et al., 2021) is a promoter for the use of LNG. All these alternative fuels have shown great promise in emission reduction, and availability while fuel savings while at berth. With the arguments posed by these authors, it is glaring that for OPS to achieve its intend usage and benefit, it has to have more than one source of clean energy as a source (Kotrikla et al., 2017). The energy storage concept is a major game changer for the energy sector and this can be applied to OPS and (Kumar et al., 2019) is a firm supporter of this as it shows promising results in cost efficiency. This in itself could be a catalyst for the adoption of OPS and in the same vein could fast become a barrier to the adoption of OPS as it would mean the design of port grids would be cease to be the traditional as it would have to accommodate this new model (Kumar, Kumpulainen, et al., 2019).

Solutions that revolve around smart port adoption will go a long way in helping port stakeholders efficiently allocate power and berths to arriving vessels according to their power demand (Peng et al., 2021), this would make OPS more environmental and financially viable as a project to embark on for ports.

2.3.3 Technology – Transmissions

Varying power designs between nations makes transmission a barrier. According to (Adamo et al., 2014) its very cost to install cables, upgrade or install substations but it must always be done the right way to ensure the right voltage and frequency is provided in order to maintain the right power is supplied from the port to the vessel at all times (Khersonsky et al., 2007). The complexity of port grid design is heightened as a result of the necessity to take into account several factors, including technological, environmental, regulatory, and safety considerations (Kumar, Kumpulainen, et al., 2019).

The selection of high- and low-voltage solutions is a critical determinant in the design of the transmission system. According to (Paul et al., 2014) the decision will have implications for various factors, including the diameters of cables, converters, and receptacles, as well as the necessity for particular safety protocols and equipment requirements.

The financial implications of expenditures in port infrastructure and the power grid have prompted scholarly investigations into alternative approaches, including the examination of adaptive power sharing among ships via a seaport microgrid that is interconnected with several shipboard microgrids (Mutarraf et al., 2021). The development of smart grids would be necessary to accommodate innovations like distributed generation and storage (Yiğit & Acarkan, 2018). Although the costs associated with this implementation may be significant, it is anticipated that the adoption of smart grids might yield various benefits that have the potential to offset the overall expenses.

Operational factors, including cable tension, cable movements, safety protocols, and other related aspects, have a significant influence on the efficiency of connections (Paul et al.) moreover, if these factors are not appropriately designed or managed, they can have adverse effects on cargo loading and discharging processes, as well as the ability to embark in emergency situations. In order to enhance performance and save costs, it is imperative to establish a harmonised framework for protocols pertaining to operations and safety (Tseng and Pilcher). According to (Kumar et al.) The evaluation of the appropriate level of automation for operational difficulties, particularly those related to high-power OPS, must be conducted on a case-by-case basis due to the associated costs.

2.3.4 Vessel –

Fuel consumption is influenced by various factors, including the dimensions and specifications of the primary engine, auxiliary engine, and boiler. According to survey data, it has been observed that several types of vessels, including tankers and ferries, are occasionally linked to distinct fuel types and fuel consumption patterns. Consequently, the utilisation of OPS affects these vessel categories in dissimilar ways (Hulskotte & Denier van der Gon, 2010). Type of vessel have a direct influence on duration of port calls. Vessels of varying types are also linked to distinct auxiliary engines, resulting in variations in load factors, power requirements, and emissions during the vessel's time at dock. (McArthur & Osland, 2013). Vessel-based technologies, such as fuel cells, batteries, or photovoltaics, have the potential to mitigate emissions from both the primary and auxiliary engines of ships during periods of anchorage when shore connection is not feasible (Tang et al., 2018). The advantages of integrating OPS with reduced speed or a battery-powered propulsion system would not only yield benefits for activities in close proximity to ports, but also facilitate the adoption of electric short-distance shuttles, which are appealing to stakeholders with a focus on sustainability (Chang & Wang, 2012).

2.3.5 Institutional Elements

The lack of stringent national legislations on air quality is a major reason why OPS hasn't gained widespread adoption as (Tseng & Pilcher, 2015) believes OPS would never become effective without a 'convention' set aside for its adoption, (Tichavska et al., 2019) also supports that, regulations for targeted aspects of shipping must be promulgated and applied.

For the successful implementation of OPS, hard and soft rules must be proposed in terms of policies to encourage the adoption of OPS without these policies becoming a barrier in present or in the future. (Torbitt & Hildreth, 2010) is a promoter for hard rules in terms of legislations, standards and how stakeholders can be encouraged to adopt OPS.

Decarbonization and sustainability in shipping also borders a lot organizational values and incentives of various stakeholders. This can be termed as soft rules as it is incentivized by personal interest of the stakeholders (Arduino et al., 2013b). A comparative analysis of the port of Bremen/Bremerhaven in Germany and three ports in West Africa (Abidjan, Lagos, and Tema) revealed contrasting approaches. The port of Bremen/Bremerhaven has made investments in OPS for inland vessels and has also contemplated extending OPS services to other segments. In contrast, the West African ports have prioritised managerial and administrative development, with a particular focus on addressing immediate sustainability concerns identified by local stakeholders. These concerns primarily revolve around waste management, pollution control, and water ballast management. (Lawer et al., 2019). Stakeholders in Europe are more receptive to using technology to combat environmental issues than their counterparts in Africa. The enforcement of widespread adoption of OPS without hard rules might be easier to achieve in some regions than some other regions depending on the values of the stakeholders involved.

2.3.6 Economic Elements

Even though OPS is environmentally and economically viable, there is a cost element to it and this is an established barrier to adoption by ports and ship owners. According to (Kumar, Kumpulainen, et al., 2019) states that there are four barriers that work against OPS adoption: uncertainty about investment and ownership status of the infrastructure, high cost of retrofitting of vessels, existing tax systems that favors onboard generation of electricity and OPS infrastructure that's not economically viable.

The cost element of the OPS isn't a one-off cost as it is divided into Capital and Operational cost elements, although they are both linked. The setup cost been very expensive has led to the use of various financial vehicles to fund the infrastructure cost, one of such vehicles is using a Blended Finance approach to implementation.

Capital costs exist with both the port and vessel owners especially when they are not newly built vessels, they have to be retrofitted and this could be viable or not depending on the remaining useful life of the vessel.

2.3.7 Blended Finance

The concept of Blending Finance is majorly for de-risking investments that could be naturally termed risky. From the barriers of adoption of OPS and the various externalities that influences the widespread adoption, it can be agreed that OPS and its attendant components qualifies for the need for finance blending especially in developing countries.

There has been a worldwide shift to sustainability in recent times and this is further encouraged by the need to mitigate climate change, fossil fuel burning and its attendant emissions have given an impetus for the world's push to electrification of activities that are traditionally reliant on various energy sources the world considers unclean.

Blended finance has emerged as a crucial mechanism for addressing the growing financial gap associated with achieving the Sustainable Development Goals (SDGs), hence making impact investment a vital tool. Blended finance refers to a strategic framework that effectively harnesses private investment with public and charitable capital in order to advance the Sustainable Development Goals (SDGs) through using financial resources (Chirambo, 2021), The originality of the blended finance idea is derived from its ability to effectively coordinate a diverse group of investors and utilise innovative technologies to achieve a common set of financial and development objectives that align with the Sustainable Development Goals (SDGs) (idfc, 2019).

The concept of Blended Finance is for de-risking investments, risk guarantees offer borrowers with technical and infrastructural support in their efforts to address challenges related to poverty, malnutrition, illiteracy, and sanitation. Within the framework of the PRG plan, philanthropic capital is utilised as a means of providing a risk guarantee, with the objective of generating financial and economic additionality by leveraging the multiplier effect.

2.3.8 SDGs

The United Nations has formulated an agenda that aims to execute 17 Sustainable Development Goals (SDGs) together with 169 goals. This agenda represents a significant move away from a narrow focus on economic growth, towards the establishment of a more robust and advanced economy (D'Souza & Jain, 2022). The growing need and shortfall of USD 4.2 trillion in achieving the Sustainable Development Goals (SDGs) has led to a focus on streamlining impact investments.

This has generated significant interest among academicians, policymakers, and researchers in the field of sustainable financing (Blended Finance | Convergence, n.d.). The primary objective of impact investments is to make a positive contribution to sustainability and enhance social welfare by utilising blended financing strategies (Blended Finance in the Poorest Countries: The Need for a Better Approach, n.d.), private and philanthropic investors are investigating blended finance mechanisms, such as PRGs, to use the required CSR expenditure by leveraging the financial resources to increase the spillover effect. One of the primary objectives of blended finance is to facilitate the advancement of marginalized segments of society, who possess the potential to contribute to economic expansion and progress, thereby surmounting poverty (Arora & Sarker, 2022). Blended finance is a component of developmental finance that is special purpose vehicle for development of infrastructure but designed to de-risk capital investments.

2.3.9 Climate Finance

The impact of climate change on an economy's financial and economic challenges has exhibited significant volatility (Adhikari, 2022). The adverse consequences of climatic circumstances, such as elevated carbon footprints, diminished utilisation of cleaner energy sources, and water pollution, among other factors, have been observed to have harmful effects on human health. Private investment is widely seen as a crucial factor in mitigating the detrimental and unavoidable consequences of climate change. The contribution of financial markets to the improvement of climatic conditions has played a key role (Gonçalves et al., 2022).

3.0 Chapter 3: Methodology

3.1 Research Design

In assessing the implications of OPS technology at Apapa Port in Lagos, this research encompasses a multi-faceted approach.

1. Quantitative Methodology: This measures factors such as investment costs, savings, and quantifiable environmental benefits of the technology.

2. Qualitative Assessment: Here, the study delves into:
 - The intricacies of blended finance models for OPS technology, evaluating stakeholder perspectives, challenges, and potential financing strategies.
 - The SWOT analysis of OPS technology itself, which looks at its strengths, weaknesses, opportunities, and threats, thereby providing insights into its viability.
 - A separate SWOT analysis focusing on blended finance for clean and affordable energy, highlighting the potential advantages and challenges of this financing mechanism.

3. Desktop Research: An exhaustive review of existing literature and data from reputable sources ensures the study is well-informed and contextualized.

Collectively, these methods offer a rounded understanding of both the technological and financial aspects of OPS. The aim is to equip stakeholders with comprehensive insights for informed decision-making regarding its adoption at Apapa Port.

3.2 Data Collection

To better understand port performance, we collected extensive data on various operational metrics, focusing on cargo types, container traffic, vessel arrival frequencies, and ship durations at the port. Key metrics such as ship waiting times and terminal berth occupancy rates were prioritized. Our main data source was the

Nigerian Maritime Administration and Safety Agency (NIMASA) for 2022. Besides NIMASA, our study explored financial aspects, particularly the investment in OPS. Comprehensive desk research led us to various resources, including MTCC-Africa, UNEP, ENTEC, Clarkson, and other online platforms, all of which are cited in our research.

3.3 Desktop Research:

A detailed literature review was conducted on the OPS systems, segmented into three core technical components: Ports, Transmission, and Vessel. The research also categorized the challenges and incentives for OPS adoption into four key areas:

i. Technology & Operations: Examining the technical and operational aspects of OPS.

ii. Institutional Factors: Assessing the regulatory and policy landscape.

iii. Economic Concerns: Evaluating the financial outcomes and challenges of OPS adoption.

iv. Stakeholder Dynamics: Understanding the roles and views of key entities like port authorities and shipping firms.

Furthermore, the review delved into the potential of blended finance for OPS, exploring how public and private funding can collaboratively support these eco-friendly projects.

3.4 Data Analysis

3.4.1 Net Present Value and Internal Rate of Return

To assess the economic feasibility of OPS infrastructures, the Net Present Value (NPV) analysis was employed. NPV calculates the present value of future cash inflows and outflows, essentially gauging the net value today of future financial activities. For our study, detailed data on potential costs and expected benefits of OPS was gathered. Microsoft Excel was used for this complex financial analysis, with specific models built to input all financial factors. The goal is to provide stakeholders with insights into potential returns on their OPS investments.

NPV= $\sum Ai\ (1+r)\ i\ n\ i$=1 – C

In brief, the NPV formula is:

n is project life,

Ai is net cash flow at the end of the year i,

r is discount rate,

C is initial capital expenditure.

A positive NPV suggests a worthwhile investment, while a negative one might indicate otherwise. However, NPV is just one tool and should be combined with other methods for a full project assessment.

Internal Rate of Return

The Internal Rate of Return (IRR) is a financial metric used to evaluate the potential profitability of an investment or project. It represents the discount rate at which the sum of the present values of future cash flows equals the initial investment. In simpler terms, it helps in determining the rate at which an investment breaks even in terms of net present value (NPV). In essence, a higher IRR indicates a more attractive investment opportunity, as it implies a higher potential for returns compared to the initial capital outlay. This makes the IRR a critical tool in investment analysis and decision-making for businesses and investors alike.

$$1RR = \sum_{n=0}^{n} \frac{AC_n}{(1+r)} n = 0$$

IRR however, was calculated using the excel spreadsheet.

3.4.2 Monte Carlo Simulation

When assessing OPS infrastructures, various uncertainties exist, from initial costs to potential savings and broader benefits. Given these complexities, the Monte Carlo simulation, an algorithm that considers variable factors, was employed. By simulating multiple outcomes, it highlights both positive scenarios and possible challenges. For our study, we used the 'Crystal Ball' software to visualize various financial and operational outcomes. This method offers stakeholders a clearer view of potential returns and risks, enabling informed decision-making on OPS investments.

3.4.3 Emissions Analysis

Quantitative data, highlighting emissions from ships using onboard generators, will be contrasted with potential emissions savings from OPS. This comparison aims to quantify the environmental benefits brought about by the technology.

3.5 Tools and Software

To fully grasp the financial and environmental impacts of OPS infrastructures, I utilize quantitative methods, notably the Net Present Value (NPV) and emissions-related calculations. Microsoft Excel will facilitate these complex analyses, being especially suited for financial and environmental metric evaluations. However, due to uncertainties in investment and operational projections, I also use the 'Crystal Ball' add-in for Excel. This tool conducts Monte Carlo simulations, randomizing inputs to explore varied scenarios.

4.0 Chapter 4: OPS AND BLENDED FINANCE.

The term OPS dates back to the era of using coal fired engines for shipping, engines were always shut off for the iron to cool off at berth. The concept of OPS or Alternative Marine Power of OPS is now been adopted as a major low hanging fruit in the fight against climate change and the shift towards the world's shift from burning fossil fuels because of the resultant effects of fossils fuels. It has been scientifically studied and concluded that the burning of fossil fuels is an important driver to many environmental impacts, thereby cause and effect of numerous environmental problems amongst many other underlying other issues of the surrounding continued reliance on fossil fuel for energy production and consumption (Huijbregts et al., 2006).

The introduction of OPS within port environments presents a ground breaking solution to tackle the maritime industry's challenges in environmental sustainability and operational efficiency. Nevertheless, the widespread adoption of this approach faces significant hurdles. A primary barrier is the substantial financial investment required to establish OPS infrastructure, encompassing the installation of high-voltage shore connection systems. Achieving compatibility and standardization across diverse ship types with varying power needs is a complex undertaking. The implementation process is further complicated by regulatory compliance and certification procedures. Coordinating operational availability with shipping companies' schedules and activities demands meticulous and detailed planning. Despite these challenges, the incentives for adopting OPS are compelling. Stricter environmental regulations and the industry's dedication to emission reduction leads to a substantial decrease in air pollution and greenhouse gas emissions. OPS implementation not only improves local air quality and mitigates the impact of noise pollution, but also yields significant long-term cost savings for maritime enterprises. Moreover, the use of OPS aligns with corporate social responsibility initiatives, showcasing a commitment to sustainable maritime practices and nurturing positive community relationships. Overall, the benefits of OPS far outweigh the challenges, offering a clear path towards a more environmentally sustainable and operationally efficient future for port operations.

Figure 2: Benefits of shore power

Source: ShorePower Benefits (Adapted from Altran 2008 p. toolkit shorepower)

4.1 Environmental Benefits

No Emissions: When ships use their onboard diesel generators while at berth, they emit harmful pollutants such as nitrogen oxides (NOx), sulfur oxides (SOx), carbon dioxide (CO_2), and particulate matter. By connecting to shore power, these emissions will be eliminated or drastically reduced, depending on the source of the shore-based electricity.

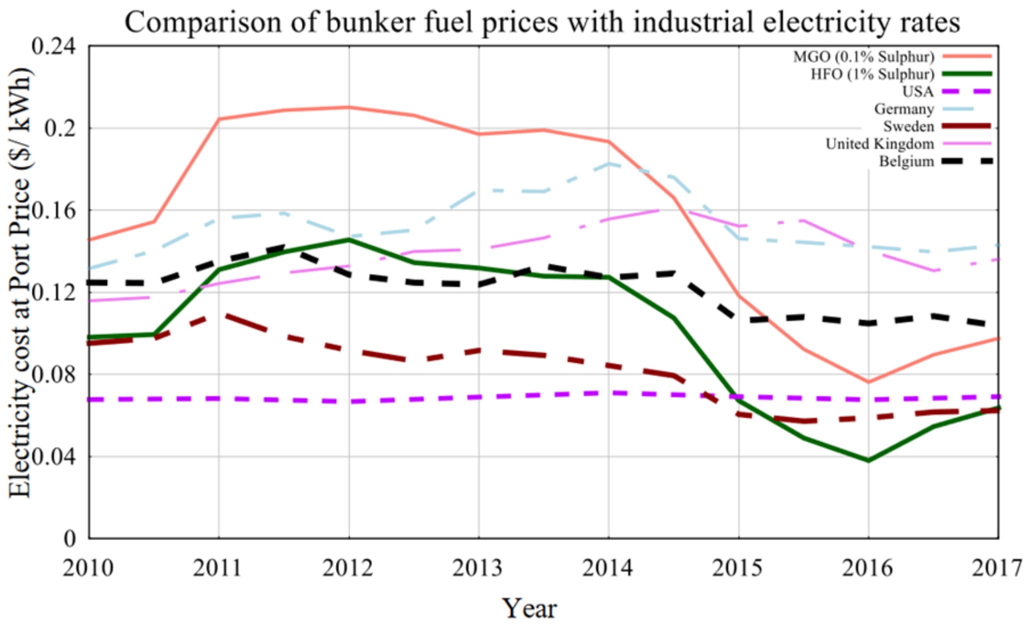
Health Benefits (Improved Air Quality): By reducing emissions at ports, OPS can lead to better air quality in and around port cities. This can have a direct impact on the health of the community, reducing respiratory problems, and other health issues linked to air pollution. Worldwide concerns have about air quality and emissions is also a huge driver for the encouragement of OPS as a means of improving the air quality around port and port cities (Prousalidis et al., 2014)

Noise and Vibrations: Turning off the ship's engines reduces noise and vibrations, making the port environment less quiet and less disruptive for both port workers and neighbouring coastal communities. This advantage is not limited to anthropogenic communities, marine mammals also benefit from the effects suffered from noise and vibrations from auxiliary engines while at berth.

4.2 Economic Benefits

Fuel Savings: Using shore power can lead to substantial fuel savings for shipping companies, as marine fuel can be expensive. The price volatility of bunker cost over the years have significant impact on cost of shipping and the resultant profit margin enjoyed by shipping companies, when faced with the possibility of burning less fuel for shipping activities, shipping companies have been seen to embrace or encourage the implantation of OPS technology on board their vessel especially as it relates to retro fitting of existing marine assets to adapt to this technology.

Figure 3: Cost of generating 1KWh of power using marine fuel vs buying 1KWh from the national grid



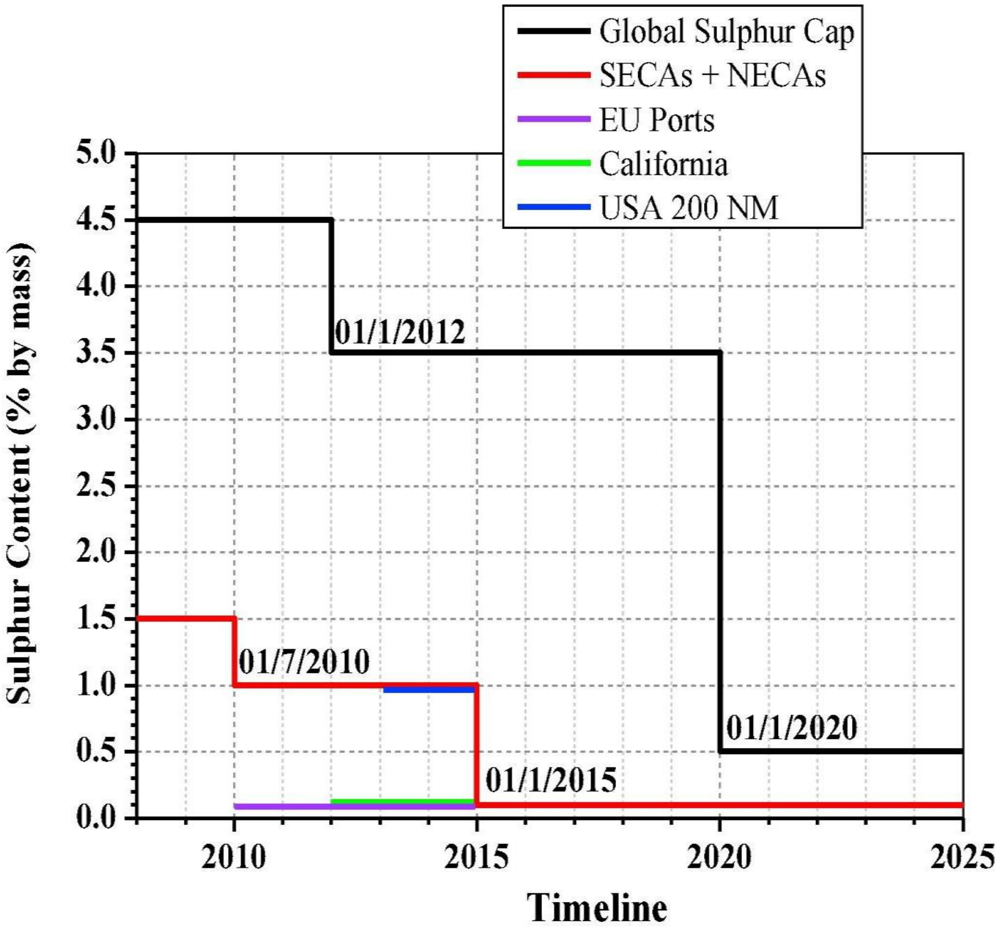
Source: (Zis, 2019)

Low Maintenance Cost: Relying on shore power can reduce wear and tear on the ship's engines and generators, leading to longer engine lifespans and decreased maintenance costs. Depreciation cost is a financial cost that assets suffer through usage amongst other factors, OPS extends the life of the vessel through less usage of the onboard generators.

Future-proofing: As environmental regulations become stricter, ships that can connect to shore power might face fewer restrictions and fees. The world is fast becoming an environmentally sustainability hub, there would be a continued shift towards viable environmental options of doing things, as things progress along this environmental lines, there would be pressure from stakeholders for ports to become Emission Controlled Areas and vessels that are not prepared for this shift would become automatically obsolete as it would not be able to fully operate in her full capacity as allowed port of calls would become limited as time goes by.

Regulatory Compliance: Some regions, environmental regulations require ships to use low-sulphur fuels or to reduce their emissions while at port. OPS provides a solution to comply with these regulations without having to switch fuels or invest in exhaust cleaning systems as this take the emission reduction responsibility from the vessel to the port operators.

Figure 4: Global Sulphur Cap as per IMO Regulations



Source: (Chu Van et al., 2019) Global impacts of recent IMO regulations on marine fuel oil refining processes and ship emissions

Energy Diversification: Depending on the local energy grid, shore power can come from a more diverse range of sources, including renewable energy. This can be a more sustainable and stable source of power compared to marine fuels. The world has its sights on creating an avenue for creating access to affordable and clean energy for all and sundry, so the shift to Renewables as a constant energy source is a matter of when as this OPS the agenda at the highest level of world governance.

Reputation and Corporate Responsibility: Implementing and using OPS can bolster a company's environmental and sustainability credentials. Being environmentally responsible can be good for public relations and may appeal to certain customers or stakeholders. A very good example of this is the attendant recognition that comes with a port declaring its green status, the port of Antwerp and Rotterdam have been enjoying this status in time past and they still do.

Despite these advantages, the adoption of OPS requires significant infrastructure investments at ports and modifications to ships. The upfront costs and the variations in electrical standards across the globe can be challenges, although it is worthy of note that the Institute of Electrical and Electronic Engineering have come up with standards as regards design and specification of OPS equipment (Caprara et al., 2022).

4.3 PORTS THAT HAVE IMPLEMENTED OPS.

Despite the advantages inherent in the implementation of the OPS technology, not many berths within a port have the necessary infrastructure to cater for this feature. As environmental and clean energy legislations are tightened, it is expected that more ports and vessels prepare for implementation and that the adoption of this technology becomes widespread.

IMO environmental centric conventions have in recent times served as an impetus in encouraging stakeholders to create and pursue more environmentally focused goals and objectives. The following are ports around the world that have successfully implemented this technology:

Table 1: List of Ports that have successfully implemented the OPS technology

Introduction	**Port**	**Country**	**Capacity (MW)**	**Frequency (Kv)**	**Voltage (Kv)**	**Ship type**
200	Gothenburg	Sweeden	1.25-2.5	50/60	6.6./11	RoRo ROPAX
2000	Zeebrugge	Belgium	1.25	50	6.6	RoRo
2001	Juneau	U.S.A	7-9	60	6.5/11	Cruise

2004	Los Angeles	U.S.A	5.7-60	60	6.6	Container, Cruise
2005	Seattle	U.S.A.	12.8	60	6.6/11	Cruise
2006	Kemi	Finland		50	6.6	ROPAX
2006	Haminakotka	Finland		50	6.6	ROPAX
2006	Stockholm	Sweden	2.5	50	0.4/0.69	RoRo
2006	Oulu	Finland		50	6.6	ROPAX
2008	Antwerp	Belgium	0.8	50/60	6.6	Container
2008	Lubeck	Germany	2.2	50	6	ROPAX
2009	Vancouver	Canada	16	60	6.6/11	Cruise
2010	San Diego	U.S.A.	16	60	6.6/11	Cruise
2010	San Francisco	U.S.A	16	60	6.6/11	Cruise
2010	Verko Kariskrona	Sweden	2.5	50		Cruise
2010	Amsterdam	Netherlands	No further information found			
2011	Long Beach	U.S.A.	16	60	6.6/0.48	Cruise
2011	Oslo	Norway	4.5	50	11	Cruise
2012	Prince Rupert	Canada	7.5	60	6.6	
2012	Rotterdam	Netherlands	2.8	60	11	ROPAX
2012	Oakland	U.S.A.				
2013	Ystad	Sweden	6.25-10	50/60	11	Cruise
2012	Helsinki	Finalnd	No further information found			
2013	Trelleborg	Sweden	0.32	50	10.5	ROPAX
2014	Riga	Latvia				
2015	Bergen	Norway		50	0.4/0.69	
2015	Hamburg	Germany	12	50/60	6/10 (50 Hz), 6.6-10	Cruise

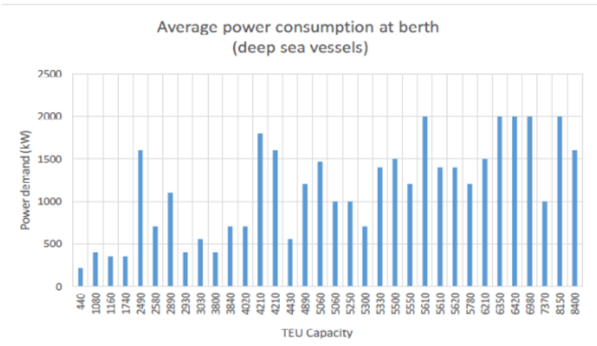
					(60 Hz)	
2015	Civitavecchia	Italy	No further information found			

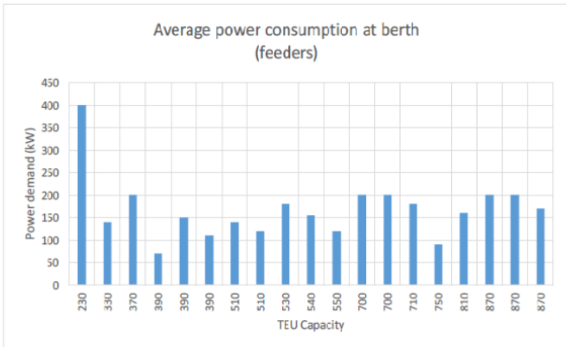
These above ports have successfully implemented Onshore Power system which is another name for OPS.

4.4 OPS researches into Greek Ports.

A series of research works have been made into the Power Demand of container vessels. One of such researches was carried out on the Port of Rotterdam;

Figure 5: Average Power Consumption at Berth





Source:

Table 2: Power Capacity-Typical Spec

Power Capacity	Typical spec
<100kW	230/400/440V – 50/60hz
100 – 500kW	400/440/690V – 50/60hz
500-1000kW	690V/6.6/11kV – 50/60hz
>1MW	6.6/11kV – 50/60hz

Source: (*Shore Power*, n.d.)

Table 3: Typical system requirements for different vessel and sizes

Vessel types	<= 999	1000 – 4999 GT	5000 – 9999 GT	10000 – 24999 GT	25000 – 49999 GT	50000 – 99999 GT	>= 100000 GT
Oil tankers	230/400/440V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz	690V/6.6/11kVV – 50/60hz	690V/6.6/11kVV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz
Chemical/product tankers	400/440/690V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz		
Gas tankers	400/440/690V – 50/60hz	400/440/690V – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz
Bulk carriers	230/400/440V – 50/60hz	400/440/690V – 50/60hz	400/440/690V – 50/60hz	400/440/690V – 50/60hz	400/440/690V – 50/60hz	690V/6.6 /11kVV – 50/60hz	
General cargo	230/400/440V – 50/60hz	400/440/690V – 50/60hz	400/440/690V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz		
Containers vessels		400/440/690V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz
Ro Ro vessels	230/400/440V – 50/60hz	400/440/690V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz	690V/6.6/11kVV – 50/60hz	6.6/11kV – 50/60hz	
Reefers	230/400/440V – 50/60hz	400/440/690V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz			
Passengers vessels	230/400/440V – 50/60hz	400/440/690V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz
Offshore supply vessel	230/400/440V – 50/60hz	400/440/690V – 50/60hz	6.6/11kV – 50/60hz				
Other offshore service vessels	230/400/440V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz	690V/6.6/11kVV – 50/60hz	690V/6.6/11kVV – 50/60hz	690V/6.6 /11kVV – 50/60hz	690V/6.6 /11kVV – 50/60hz
Other activities	230/400/440V – 50/60hz	400/440/690V – 50/60hz	690V/6.6/11kVV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz	6.6/11kV – 50/60hz
Fishing vessels	230/400/440V – 50/60hz	400/440/690V – 50/60hz	6.6/11kV – 50/60hz				

Source: (*Shore Power*, n.d.)

Table 4: The cost of implementing onboard vessel may vary vessel to vessel as per designandotherexternalities.

Investment cost for vessel (USD)	**1000 – 4999 GT**	**5000 – 9999 GT**	**10000 – 24999 GT**	**25000 – 49999 GT**	**50000 – 99999 GT**	**>= 100000 GT**
Crude tankers	$50 000 – $350 000	$100 000 – $400 000	$100 000 – $400 000	$100 000 – $400 000	$300 000 – $750 000	$300 000 –$750 000
Chemical / product tankers	$50 000 – $350 000	$100 000 – $400 000	$300 000 – $750 000	$300 000 – $750 000		
Gas tankers	$50 000 – $350 000	$300 000 – $750 000	$300 000 – $750 000	$300 000 – $750 000	$300 000 – $750 000	$300 000 –$750 000
Bulk carriers	$50 000 – $350 000	$50 000 – $350 000	0,5 – 3 Mill	0,5 – 3 Mill	$100 000 – $400 000	
General cargo	$50 000 – $350 000	$50 000 – $350 000	0,5 – 3 Mill	$100 000 – $400 000		
Container vessels	$50 000 – $350 000	$50 000 – $350 000	$100 000 – $400 000	$300 000 – $750 000	$300 000 – $750 000	$300 000 –$750 000
Ro Ro vessels	$50 000 – $350 000	$50 000 – $350 000	$100 000 – $400 000	$100 000 – $400 000	$300 000 – $750 000	
Reefer	$50 000 – $350 000	$50 000 – $350 000	$100 000 – $400 000			
Passenger ship	$50 000 – $350 000	$50 000 – $350 000	$100 000 – $400 000	$300 000 – $750 000	$300 000 – $750 000	$300 000 –$750 000
Offshore supply ship	$50 000 – $350 000	$100 000 – $400 000				
Other offshore service ships	$50 000 – $ 350 000	$100 000 – $400 000	$100 000 – $400 000	$100 000 – $400 000	$100 000 – $400 000	$100 000 – $400 000
Other activities	$50 000 – $ 350 000	$100 000 – $400 000	$300 000 – $750 000	$300 000 – $750 000	$300 000 – $750 000	$300 000 –$750 000
Fishing vessels	$50 000 – $ 350 000	$100 000 – $400 000				

Source: (*Shore Power*, n.d.)

4.5 More on OPS

The design of OPS equipment’s can vary accordingly but all installations must be in line with requirements with ISO/IEC/IEEE 80005-1.

Frequency Converter - A huge component of most installation of OPS infrastructure is the frequency converter, because of the disparity between the frequency on most vessels and the one available at the grid on the port side of things, the need of a frequency converter becomes imperative. Past academic studies have shown that the cost of frequency converter a third of the cost of infrastructure.

Voltage Transformers

Every type of OPS (CI) configuration requires the use of multiple voltage transformers. In the case of busbars linked to frequency converters for 60 Hz current transmission, the initial role of voltage transformers is to adjust the current's voltage from the national grid's level to the specific input voltage needed by each frequency converter.

Figure 6: Voltage map of the world

Source: (*Find the Right Voltage Converter with Our Buying Guide*, n.d.-b)

Double busbar system and switchgears

Reiterating for clarity, it's crucial to note that the dual busbar system integrated into the port's main substation allows for concurrent utilization of both 50 Hz and 60 Hz shore power at each berth terminal. This system must align with the OPS installation necessities, specifically in terms of the power and voltage demand of the berth terminals.

Circuit Breakers

Circuit breakers ensure the seamless transition of a system's current to zero, safeguarding other components like cables, transformers, and substations from potential damage. This notion of gradual current reduction is attained via an insulation medium, which extinguishes the electrical arc by providing sufficient resistance to prevent arc propagation. The type of insulation medium used can differ from one installation to another. Commonly found on the market are circuit breakers insulated by vacuum or gas.

Cables

Options for cable reel systems can differ depending on the specific application. While fixed solutions can be installed at each berth, there are also mobile alternatives. A mobile cable reel system offers not just an easy way to handle lengthy cables, but also enhances the overall flexibility of the entire installation, given its ability to be used across multiple berths.

Connection Boxes

The last phase of choosing shore-side equipment for a OPS (CI) installation involves selecting the appropriate connection boxes. Positioned directly at the edge of each quay, the number of these boxes depends on the types of vessels that the berth is designed to accommodate.

Global Best Practices

The best practices for OPS is tilted towards the United Nations Sustainable Goals 3,7,9,11,13,14 and 17. OPS aligns with these sdgs as it also borders on the motivations for OPS implementation and adoption.

Blended Finance.

Blended finance is a strategy for enhancing project funding by mixing various forms of funding from various sources and/or for various goals, which support development, social, environmental, or humanitarian objectives and produce financial benefits (Gibson et al., 2022). The use of concessional funds that is extended below market rates to attract other sources of funding make less viable projects bankable, this serves as a project de-risker (Christiansen, 2021).

The 2015 Paris Agreement and the United Nations' Sustainable Development Goals marked a pivotal moment in transitioning from discussion to tangible measures to tackle two of the globe's most pressing issues with clear objectives of more access to energy and reduction of global warming that is a resultant effect of ghg emissions (Tonkonogy et al., 2018). Nigeria is an oil rich country but energy poor. Nigeria has huge oil and gas deposits but access to electrification remains poor.

Blended finance has been advocated as a mechanism capable of leveraging billions of dollars to mobilise trillions of dollars of private resources through Official Document Assistance known as Billions to Trillions (Choi & Seiger, 2020).

The rationale underlying mixed finance is straightforward. Private investors frequently exhibit hesitancy when it comes to allocating investments towards technologies and systems that lack a reliable estimation of risk-adjusted returns. This reluctance originates from the presence of both perceived and actual hazards that are deemed to be significant. Developing countries face heightened levels of risk and uncertainty, primarily attributed to the underdeveloped nature of their local financial markets, information asymmetries, currency fluctuations, and political risk (Choi & Seiger, 2020).

GHG emissions, most notably carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), trap heat in the Earth's atmosphere and contribute to the greenhouse effect. This leads to global warming and subsequent climate change. Reducing these emissions is crucial to mitigate the impacts of climate change, such as rising sea levels, extreme weather events, and loss of biodiversity.
Reducing these emissions is crucial to mitigate the impacts of climate change, such as rising sea levels, extreme weather events, and loss of biodiversity. By driving investments in clean energy and other low-carbon initiatives, blended finance can play a pivotal role in reducing GHG emissions, particularly in regions where access to finance is a key barrier.

The Paris Agreement recognizes the critical role of finance in achieving its goals. Blended finance can be a tool to help mobilize the vast sums needed to transition to low-carbon and resilient economies, especially in developing countries.

Blended finance acts as a catalyst to unlock more significant sums of private capital for climate mitigation and adaptation efforts. It helps bridge the financing gap needed to achieve the goals of the Paris Agreement and transition to a more sustainable, low-carbon future.

OPS, also known as shore-to-ship power or alternative maritime power (AMP), allows ships to turn off their auxiliary engines while docked and plug into the local electrical grid. This reduces emissions, noise, and fuel consumption at ports. The implementation of OPS in Nigeria or any developing nation would involve significant infrastructural development, technology adoption, and regulatory adaptation.

Blended finance can play a pivotal role in promoting and supporting the implementation of OPS in Nigeria.

Risk Mitigation: Development Finance Institutions (DFIs) and Multilateral Development Banks (MDBs) can offer first-loss guarantees or concessional finance to reduce the perceived risk for private investors.

Leveraging Grants and Technical Assistance: Philanthropic organizations or international donor agencies can provide grants to fund feasibility studies, technology assessments, or training initiatives. This helps build a foundation for the larger infrastructure required for OPS.

Concessional Loans: DFIs or MDBs can offer loans at below-market rates to incentivize the port authority or private stakeholders to invest in OPS infrastructure. These loans can fill the financial gap that traditional banks or investors might shy away from due to perceived risks.

Equity Investments: Blended finance structures can also introduce equity investments, where public or philanthropic funds take an equity stake in an OPS project. By taking an equity position, these institutions signal confidence in the project's viability, thereby encouraging other investors.

Policy Dialogue and Advocacy: International organizations, with their global expertise, can facilitate dialogue between the Nigerian government, private sector, and local communities. They can advocate for policy reforms and regulatory frameworks that support the adoption of OPS and create an environment conducive to private investment.

Public-Private Partnerships: Governments and private entities can collaborate to develop, finance, and operate OPS facilities. Blended finance can serve as the glue that binds these partnerships, ensuring that risks and rewards are equitably shared.

Capacity Building: Blended finance mechanisms can also support training programs for local engineers, technicians, and port staff, ensuring the sustainability and effectiveness of OPS systems once they are in place.

For OPS to be successful in Nigeria, there would also be a need for:

- Stable electrical grids: To ensure that ports can supply ships with consistent power.
- Regulatory frameworks: Mandating or incentivizing ships to use OPS.
- Port infrastructure upgrades: To accommodate the necessary equipment and electrical connections.

Deploying blended finance for OPS in Nigeria involves multiple stakeholders, strategic financing instruments, and close collaboration between the public and private sectors.

Concept of Additionality

The concept of "additionality" in blended finance is fundamental. In essence, additionality refers to the unique value or impact that public or concessional funds bring to a project or investment, which wouldn't have been possible without them. This could mean making a project feasible, reducing risks to a level acceptable for private investors, or enhancing the project's social and environmental outcomes. The idea is that blended finance should not replace or crowd out private sector financing but rather should act as a catalyst to mobilize more of it.

Applying the concept of additionality to an OPS project in Nigeria can help elucidate the added value or impact that blended finance would bring to such a venture. Here's how additionality can be related to OPS in Nigeria:

Financial Additionality: Given that Nigeria is a developing economy with numerous competing infrastructural needs, sourcing funding for a niche project like OPS could be challenging. Blended finance can provide the crucial funds needed to bridge the financing gap, making the project financially feasible when private investors might view it as not sufficiently profitable or too risky.

Risk Mitigation: OPS requires significant infrastructural development and technological adoption. Given that this would be a relatively new initiative for Nigeria, it carries inherent risks. Public or concessional funds could take on the higher-risk aspects of the project, offering guarantees or covering initial costs, thus making the investment more attractive for private investors.

Demonstration Effect: By implementing a successful OPS project with the aid of blended finance, Nigeria can set a precedent for other African or developing nations. It demonstrates the viability and benefits of such projects, potentially leading to increased confidence and subsequent investments in similar projects elsewhere.

Impact Enhancement: Blended finance can ensure that the OPS project goes beyond mere functionality. With the inclusion of concessional funds, the project could incorporate higher environmental standards, better facilities, or broader community engagement, ensuring that the port and surrounding areas genuinely benefit.

Mobilization: The involvement of international or public finance actors, along with their endorsement of the project, can attract additional private sector funds that might not have been invested otherwise. The blended finance structure signals to private investors that the project has undergone rigorous assessment and is backed by credible entities, potentially leading to larger-scale investments.

Policy and Regulatory Change: The involvement of significant international or development finance actors could influence Nigerian policymakers. It could catalyze the development of supportive regulations, incentives, or mandates for ships to utilize OPS, thus ensuring the project's long-term success and sustainability.

Capacity Building and Knowledge Transfer: Blended finance can facilitate the transfer of technical expertise and best practices from regions where OPS is well-established. By building local capacity and training staff, the project ensures sustainability and the potential for future expansion.

The concept of additionality, when applied to an OPS project in Nigeria, emphasizes the unique benefits and impact that blended finance would bring. This includes not only making the project financially viable but also ensuring its long-term success, broader development impact, and potential replication in other regions.

Why is Additionality Important?

Ensuring additionality is crucial for multiple reasons:

Avoiding Market Distortions: Blended finance should complement, not compete with, private sector financing. If public funds are used when private funds would have been available, it can distort markets and crowd out private investors.

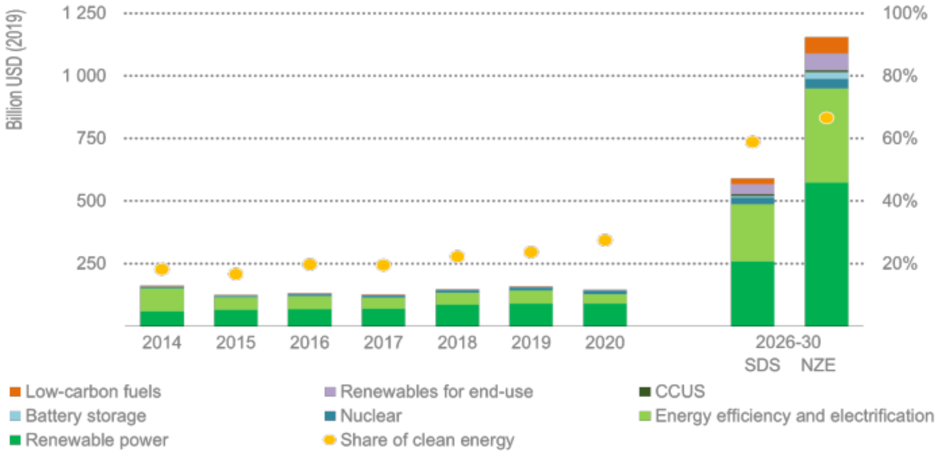
Ensuring Effective Use of Scarce Resources: Public and philanthropic resources are limited. They should be used where they can have the greatest impact, leveraging additional private resources and achieving outcomes not possible with private finance alone.

Maximizing Impact: The goal of blended finance is not just to make projects financially viable but to achieve development outcomes. Additionality ensures that the involvement of concessional capital leads to better social, environmental, or developmental impacts.

In sum, additionality ensures that blended finance is used effectively, making projects possible that wouldn't have been otherwise, and achieving broader development goals. It's a critical concept to ensure the integrity and effectiveness of blended finance interventions.

Figure 7: Clean Energy investments in Emerging and Developing Countries.

Clean energy investment in EDEs compared with projections in the IEA Sustainable Development Scenario (SDS) and Net Zero Emissions by 2050 Scenario (NZE)



Source: International Energy Agency (2021, Financing Clean Energy Transitions in Emerging and Developing Economies 2021, IEA, Paris.

5.0 Chapter 5

5.1 Lagos Port Complex (Apapa Port) Overview

Located in Apapa, Lagos State, Nigeria's commercial hub, the Lagos Port Complex, often known as the Premiere Port or Apapa Quays, stands as the earliest and most significant port in the country. Boasting five private terminals and eight jetties, it plays a crucial role in Nigeria's maritime trade and transport infrastructure.

The dynamic operations within the port are managed by five distinguished terminal operators. They are AP Moller Terminal Ltd. (APMT), ENL Consortium Ltd. (ENL), Apapa Bulk Terminal Ltd. (ABTL), Greenview Development Nigeria Ltd. (GNDL), and the Lilypond Inland Container Terminal. Additionally, two logistics bases, Eko Support Services Ltd. and Lagos Deep Offshore Logistics (LADOL), support the port's vast operations.

5.2 Port Performance Metrics:

The port can accommodate a range of vessels with varying sizes. At the anchorage, vessels with LOA 182.9 m. and a draft of 8.53 m. can be accommodated. Containers can have a draft of up to 12.0 m., bulk carriers up to 12.5 m., tankers with an LOA of 190 m. and a draft of 13.0 m., and gas carriers can have a draft of 11.0 m.

Figure 8: Aerial view of the Apapa Port berth

Source: (*2.1.1 Nigeria Port of Apapa Quays (Lagos) | Digital Logistics Capacity Assessments*, n.d.)

Figure 9: Image of the Lagos Port Complex

Source: (*2.1.1 Nigeria Port of Apapa Quays (Lagos) | Digital Logistics Capacity Assessments*, n.d.)

5.3 Sulphur Cap

As a signatory to the IMO marine pollution conventions, including SOLAS 1974 and MARPOL 73/78 (as amended), Nigeria is obligated to ensure industry compliance through its primary agency, the NIMASA. Under the legislative tenets of the Merchant Shipping Act of 2007 and the NIMASA Act of 2007, NIMASA supervises the enforcement of ratified IMO instruments. With the IMO's commitment to reducing maritime air emissions, a 0.5% sulphur cap in vessel fuel, down from the previous 3.50% since 2012, has been introduced. Exceptions exist for safety or equipment damage. NIMASA, recognizing this mandate, liaised with suppliers to ensure the availability of compliant fuel prior to the 1 January 2020 deadline.

5.4 OPS

Within the framework of the World Ports Sustainability Program (WPSP), a sophisticated OPS computational methodology has been developed. This instrument is intricately designed to provide robust and credible estimations crucial for a comprehensive cost-benefit analysis of OPS integration. The associated opportunity costs of employing OPS have been extensively outlined in preceding literature. Concurrent with the recent decarbonization directives issued by the IMO, this computational methodology has been augmented to encompass evaluations of both financial ramifications and anticipated emission reductions stemming from OPS application.

For the purposes of this investigation, the referenced OPS calculator was leveraged to derive critical data pertinent to the practicalities of OPS integration. Although the calculator is versatile, catering to an array of vessel types, this investigation specifically focuses on container vessels and reefers due to their correlative categorization within maritime typologies. Enclosed, one will find a detailed OPS calculator manual, curated with precision under the guidance of the WPSP.

Source: (*Equipment and Solutions – World Port Sustainability Program*, n.d.)

In an examination of data specific to container and reefer vessels, Microsoft Excel was employed for the analysis. Within the confines of the year 2022, seventy-five such vessels berthed, accounting for an aggregate of 157 visits and amassing a combined hoteling duration of 14,464.8 hours. Evaluating the hours docked at the Apapa port, it becomes evident that a cumulative span of 602.7 days was dedicated to a mere 75 vessels. Such statistics underscore a pronounced inefficiency within port operations, signifying considerable temporal and resource wastage.

To compute the expenditure associated with Marine Diesel Oil (MDO) during their berthing period, the total kilowatt-hours (kWh) across all 75 vessels was ascertained, culminating in a value of 43,905,809.44 kWh. Subsequently, based on findings from online scholarly sources, it was established that the energy output stands at approximately 9.963 kWh per liter of MDO.

Table 5: Showing total ton of bunker used for hoteling services at berth at Apapa port for 2022

Conversion of Kilowatts to Marine Diesel Oil	
Total Kwh	43905809.44
Kw per Liters	9.963
Liters of MDO 0.5 Bunker	4406886.424
Tons of Bunker for total kwh	4406.886424

The cumulative kilowatt-hours (kWh) for the 75 vessels, when divided by the kWh per liter metric, yielded a total of 4,406,886.424 liters. To ascertain the mass in tons of the Marine Diesel Oil (MDO) consumed, the derived liter value, 4,406,886.424 liters, was divided by 1,000. Consequently, this calculation translated to an equivalent of 4,406.886424 tons of MDO for just 75 vessels in a year, port efficiency needs to be a priority for the Port as the amount of MDO used up for hoteling activity shows port inefficiency.

To elucidate the financial implications of bunker fuel consumption, the prevailing bunker price was sourced from authoritative online databases. The aggregate expenditure on bunker fuel, in relation to the total power consumption, was deduced by multiplying the unit price of $728 per ton with the derived consumption of 4,406.886424 tons.

Table 6: Price of MDO used for hoteling services at Apapa port in 2022.

Cost of Bunker	
Total Kwh	43905809.44
Kw per Litre	9.963
Litres of MDO 0.5 Bunker	4406886.424
Tons of Bunker for total kwh	4406.886424
Price of Bunker	$ 3,190,585.77
Exchage rate of Dollar to Euro	1.07
Price of Bunker in Euro	€ 3,413,926.77

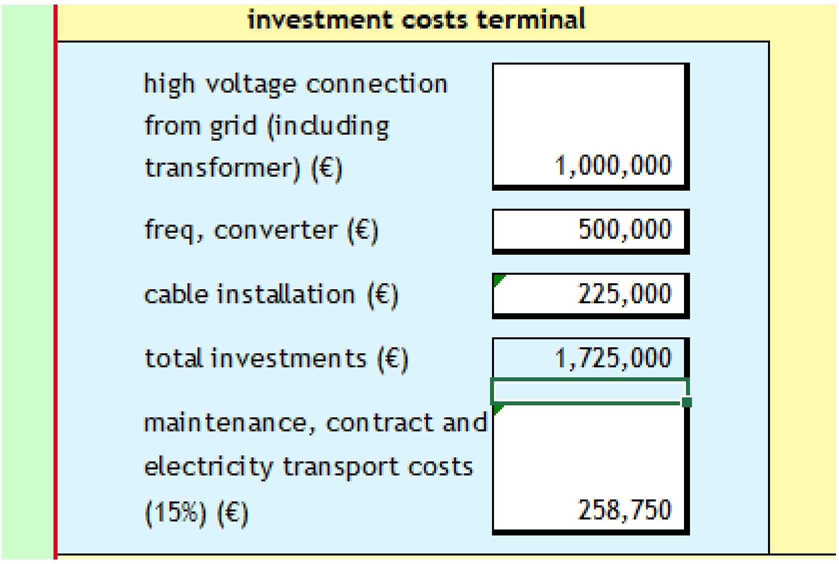
The gross amount of $3,190,585.77 was expended for the hoteling activity for just 75 vessels, this negatively impacts trade as this would make the cost of goods transported higher than necessary. This would invariably increase inflation rate.

The emission factors corresponding to 0.5% sulphur cap marine diesel oil were ascertained and subsequently incorporated into the model tailored to compute emissions emanating from power generated by the Auxiliary Engine (AE) during berthing periods.

Additionally, the emission factors associated with power derived from the national grid were procured from the esteemed National Power Generation Agency. The cumulative emissions were then computed through the multiplication of these emission factors with the power demand of individual vessels during their respective berthing phases. The resultant values were then aggregated to yield a comprehensive summation.

Furthermore, a simulation of a 10MW OPS system was executed using the specialized OPS calculator, facilitating the extraction of pertinent figures.

Figure 10: Investment Cost for OPS Terminal



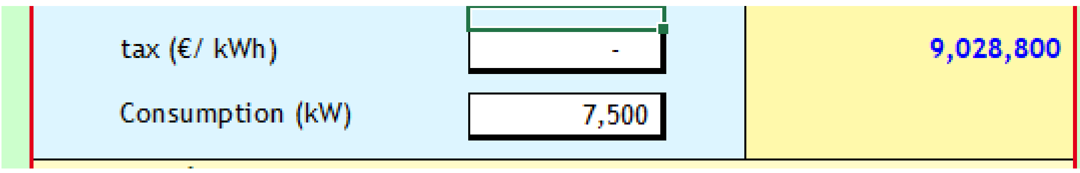
investment costs terminal	
high voltage connection from grid (including transformer) (€)	1,000,000
freq, converter (€)	500,000
cable installation (€)	225,000
total investments (€)	1,725,000
maintenance, contract and electricity transport costs (15%) (€)	258,750

Source: (*Equipment and Solutions – World Port Sustainability Program*, n.d.)

An estimate of 15% of the initial outlay have been established to be adequate for yearly maintenance of the OPS system. All components have been well accounted for in the data above.

For the establishment of a 10MW OPS system, an initial investment of 1,725,000 Euros is necessitated. Subsequent to its implementation, an annual maintenance overhead of 258,750 Euros is anticipated. An annual financial outlay amounting to 9,028,000 Euros is projected as the remittance to the Utility company for the electricity provision corresponding to the 10MW capacity.

Figure 11: Yearly payment to Power Utility Provider



tax (€/ kWh)	-	9,028,800
Consumption (kW)	7,500	

Source: (*Equipment and Solutions – World Port Sustainability Program*, n.d.)

Although payment is made for a 10MW capacity, the actual consumption recorded stands at 7,500 kW. This observed discrepancy can be attributed to the system's rated power and the inherent losses encountered during the power distribution process.

Table 7: Showing Markup and Margin for Electricity Pricing

Price Determination for Ship Owners		At 10% Markup	At 20% Markup	At 30% Markup	At 40% Markup
		0.10	0.20	30%	0.40
Amount paid to Utility Company	€ 9,028,800.00	€ 9,931,680.00	€ 10,834,560.00	€ 11,737,440.00	€ 12,640,320.00
Power Demand in kw	43905809.44	43905809.44	43905809.44	43905809.44	43905809.44
Proposed Margin	€ 0.21	0.23	0.25	€ 0.27	0.29

To ascertain an optimal unit price for power provision via the OPS to vessels, multiple scenarios were formulated. Varied percentage mark-ups were suggested. Given the composite cost, the unit price was established at 0.21 euros. Consequently, any valuation exceeding this threshold represents a profit margin.

Table 8: Showing cost of Power per kW from MDO

Amount from using AE	€ 23,728,769.86
Unit cost of kW from AE	€ 0.54

Based on the output from the OPS calculator, the unit cost for each kilowatt is quantified at 0.54 euros. Thus, any valuation below this benchmark ensures a profit margin for all stakeholders involved. A minimum price threshold of 0.23 euros was discerned as the point at which all stakeholders remain in a profitable position.

A profit margin of 0.02 euros is projected, culminating in an aggregate of 902,880 Euros. From this total, the annual maintenance expenditure is subtracted, yielding a net cash inflow of 644,130 Euros. This resultant sum will serve as a foundational value for the computation of the Net Present Value (NPV) and the Internal Rate of Return (IRR) for the envisaged project.

Table 9: Showing how yearly inflow was arrived at

Pricing Difference	€ 0.02
Margin	€ 902,880.00
Maintenance Cost	€ (258,750.00)
Inflow	€ 644,130.00

It is imperative to note that these computations are rooted in empirical data sourced from port visitations. Within the dataset, 75 vessels, on average, registered 2 port calls and maintained a berthing duration of approximately 192 hours.

Figure 12: showing the average number of calls and hours per year for container vessels that berthed in Apapa port for 2022.

A	General information	
	ships	75
	calls per year per ship	2
	hours at berth connected	192

Source: (*Equipment and Solutions – World Port Sustainability Program*, n.d.)

Utilizing this dataset provides a comprehensive insight into the expenditures ship owners would incur on MDOs, considering their consumption patterns in conjunction with the prevailing price per ton.

Figure 13: Showing operation cost from using MDO for hoteling services while at berth in Apapa port for the year 2022.

OPERATIONAL COSTS		
Input terminal		**Yearly costs (€)**
Fuel costs		
Diesel (USD/ton)	724	23,728,770
Consumption (ton/h)	1.7	

Source: (*Equipment and Solutions – World Port Sustainability Program*, n.d.)

The subsequent table delineates the potential pollution levels attributable to MDO consumption in the absence of the OPS simulation. However, a more in-depth analysis was subsequently conducted using Microsoft Excel, grounded in empirical data.

Figure 14 : Showing the pollution from using diesel per ton using the OPS calculator

POLLUTION		
Input		**pollution units**
Fuel	Diesel	
Pollutants	**Emissions (ton)**	**Pollution units**
CO_2	158906.9	
NO_x	3376.8	3,376,771
PM	104.3	1,334,818
SO_2	248.3	546,242
Total		**5,257,831**

Source: (*Equipment and Solutions – World Port Sustainability Program*, n.d.)

Table 10: Showing emissions reduced from using National Grid

Emission reductions electricity	
NOx	98%
PM	99%
SO2	58%
CO2	50%

Source: (*Equipment and Solutions – World Port Sustainability Program*, n.d.)

Utilizing electricity sourced from the Nigerian National Grid, the OPS calculator simulation posits a reduction of 98% in NOx, 99% in PM, 58% in SO2, and 50% in CO2 emissions. Nonetheless, to gain a more precise understanding beyond these simulations, supplementary computations were executed using Microsoft Excel.

NPV

In order to create a NPV model, a number of assumptions had to be made.

1. Time period of the investment:
2. Year of starting: 2023
3. Year of data: 2022
4. Life of investment: 15 years
5. All components have the same lifetime
6. Financial estimations
7. No Electricity price growing rate has been considered.
8. No Euro inflation rate has been considered.
9. Discount rate (Nigeria inflation rate): 18.5%
10. Ship calls are considered same with 2022 figures and fix for the next years.
11. Ships' energy consumption is considered same with 2022 figures and fix for the next years.
12. Ship emissions are considered same with 2022 figures and fix for the next years.
13. Calculation of cash flow at system usage rate 100%

14. 7. Initial capital cost of the investment o Initial capital cost of the OPS installation: 1,725,000.00 €
15. Annual costs: OPS total annual maintenance cost value (2022): 258,750 €
16. No loans for the initial investment have been considered in this study.
17. Nigeria is not yet part of the ECA.
18. Tax exemption status granted for the first 5 years.
19. A tax rate of 30% after the 5th year is accounted for.

Table 11: NPV for OPS system for docked container vessels at Apapa Port

	NPV for OPS system					
	Interest rate	0.185	Tax	30%		
	Year	**Net Cash Flow ($)**	**CCF**	**18.5% D.R**	**DCF**	**CDCF**
CAPEX	0	€ (1,725,000.00)	€ (1,725,000.00)	1	€ (1,725,000.00)	€ (1,725,000.00
OPEX	1	€ 644,130.00	€ (1,080,870.00)	1.185	€ 543,569.62	€ (1,181,430.38
	2	€ 644,130.00	€ (436,740.00)	1.404225	€ 458,708.54	€ (722,721.84)
	3	€ 644,130.00	€ 207,390.00	1.664006625	€ 387,095.81	€ (335,626.02)
	4	€ 644,130.00	€ 851,520.00	1.971847851	€ 326,663.13	€ (8,962.89)
	5	€ 644,130.00	€ 1,495,650.00	2.336639703	€ 275,665.09	€ 266,702.20
	6	€ 450,891.00	€ 1,946,541.00	2.768918048	€ 162,840.14	€ 429,542.34

7	€ 450,891.00	€ 2,397,432.00	3.281167887	€ 137,417.84	€ 566,960.18
8	€ 450,891.00	€ 2,848,323.00	3.888183946	€ 115,964.42	€ 682,924.60
9	€ 450,891.00	€ 3,299,214.00	4.607497976	€ 97,860.27	€ 780,784.87
10	€ 450,891.00	€ 3,750,105.00	5.459885102	€ 82,582.51	€ 863,367.38
11	€ 450,891.00	€ 4,200,996.00	6.469963845	€ 69,689.88	€ 933,057.26
12	€ 450,891.00	€ 4,651,887.00	7.666907157	€ 58,810.02	€ 991,867.28
13	€ 450,891.00	€ 5,102,778.00	9.085284981	€ 49,628.71	€ 1,041,496.00
14	€ 450,891.00	€ 5,553,669.00	10.7660627	€ 41,880.77	€ 1,083,376.77
15	€ 450,891.00	€ 6,004,560.00	12.7577843	€ 35,342.42	€ 1,118,719.19
PBP	**3.32**	**years**			
NPV	**1118719.19**				
IRR	**34%**				

The above table shows the NPV and IRR of the investment for the project, it also shows the payback period (PBP) of the OPS. The pbp is in 3.32 years and this means the project pays back the initial outlay very early on and this means the project is economically viable.

A positive NPV of €1,118,719.19 at the end of the 15th year indicates this project is a viable one and the project is expected to generate a 34% return on investment every year through the lifespan of this project.

The subsequent table presents an optimal scenario wherein each vessel docking at the Apapa container berth is equipped with OPS capabilities and seamlessly integrates with the system.

An initial capital outlay of €1,725,000.00 is projected, accompanied by an annual upkeep expense of €258,000.00. Following the deduction of maintenance costs, a net cash inflow of €644,130.00 is anticipated from the energy sales.

In alignment with Nigeria's extant policies, pioneering initiatives are often rewarded with a "pioneer status", a recognition that was bestowed upon this project. This status confers a tax exemption for an initial duration of five years, a benefit that is conspicuously manifested in the table's financial breakdown.

Post the culmination of this tax-relief period, taxation is expected to be levied at a rate of 30%. The financial projections have been adjusted to accommodate this, with the anticipated revenue from the sixth year onward being curtailed to €450,891.00, mirroring the nation's fiscal regulations.

It's noteworthy to mention that this project neither received governmental subsidies nor was it buttressed by external loans.

Table 12: Social Cost of Emissions

Social cost factors.

Compartment	Pollutant	Cost Factor
Air	Carbon dioxide	0.0566 €/kg
	Carbon monoxide	0.0958 €/kg
	Dinitrogen monoxide	15 €/kg
	Methane	1.75 €/kg
	Nitrogen oxides	34.7 €/kg
	Non-methane volatile organic compounds	2.1 €/kg
	Particulates$_{2.5}$	79.5 €/kg
	Sulphur dioxide	24.9 €/kg
Water	Arsenic	433 €/kg
	Cadmium	6.57 €/kg
	Lead	5.85 €/kg
	Mercury	1980 €/kg
Soil	Arsenic	69.3 €/kg
	Cadmium	2040 €/kg
	Chromium	0.000636 €/kg
	Lead	14.2 €/kg
	Mercury	1550 €/kg

The aforementioned data facilitated the calculation of health-related costs arising from emissions produced by the vessels' exhaust while at berth. Subsequent to these computations, the costs were standardized to a per-ton basis.

Table 13:showing social cost of emission per ton

MARGINAL DAMAGES POLLUTING AGENT FOR TON OF EMISSION	
NOx	$ 34,700.00
SOx	$ 24,900.00
PM2	$ 79,500.00
CO2	$ 56.600

5.5 Scenario 1: 100% Ships using OPS

Utilizing the established per-ton emission costs, the cumulative health-related expenses for the 75 vessels were calculated. The results indicate a potential savings of €23,422,831.71 should all 75 vessels integrate the OPS system. This financial reprieve not only underscores the project's viability but also translates to a substantial governmental savings of €23,422,831.71. In terms of emission reductions, the findings revealed savings of 81.3% for NOx, 99.5% for SOx, 86.3% for PM, and 36.4% for CO2.

Table 14: Showing Total savings that would accrue to the society from using OPS by all container vessels that docked at Apapa port in 2022.

SCENARIO 1 - 100% SHIPS USE OPS FOR THE YEAR 2022 - electricity production as per emission factors for Nigeria				
	Nox (t)	SO2 (t)	PM (t)	CO2
Health costs deriving from emissions from ships with auxiliary engines running	€ 21,177,089.07	€ 4,700,995.02	€ 1,047,153.56	€ 1,714,697.48
Health costs deriving from Emissions Ships using OPS	€ 3,961,182.13	€ 21,865.09	€ 143,110.99	€ 1,090,945.21
DIFFERENCE	€ 17,215,906.94	€ 4,679,129.92	€ 904,042.57	€ 623,752.27
% VARIATION	81.3%	99.5%	86.3%	36.4%
Total health cost savings by using OPS				€ 23,422,831.71

5.6 Scenario 2: 50% of Ships Using OPS

Drawing upon the previously delineated per-ton emission costs, the health-related expenses for half of the 75 vessels were ascertained. The findings suggest a prospective savings of €11,711,415.85 if only half of these vessels were to adopt the OPS system. This substantial economic alleviation not only reinforces the project's viability but would also represent a noteworthy governmental savings of €11,711,415.85. The emission reductions remained consistent, with savings of 81.3% for NOx, 99.5% for SOx, 86.3% for PM, and 36.4% for CO2.

Table 15: Showing total health savings in monetary value if only half of the container vessels that berthed in Apapa Port in the year 2022 used OPS.

SCENARIO 2 - 50% SHIPS USE OPS FOR THE YEAR 2022 - electricity production as per emission factors for Nigeria				
	Nox (t)	SO2 (t)	PM (t)	CO2
Health costs deriving from emissions from ships with auxiliary engines running	€ 10,588,544.53	€ 2,350,497.51	€ 523,576.78	€ 857,348.74
Health costs deriving from Emissions Ships using OPS	€ 1,980,591.06	€ 10,932.55	€ 71,555.49	€ 545,472.60
DIFFERENCE	€ 8,607,953.47	€ 2,339,564.96	€ 452,021.28	€ 311,876.14
% VARIATION	81.3%	99.5%	86.3%	36.4%
Total health cost savings by using OPS				€ 11,711,415.85

The subsequent analysis provides a projection of potential health cost savings in the event that all 75 vessels maintain their current emission levels. This forecast assumes a static emission pricing structure over time and contemplates the scenario wherein all 75 vessels adopt the OPS during their berthing periods in Nigeria.

Table 16: Forecast of 100% use of OPS system in 20 years using social cost as a yardstick.

Total health cost benefits - forecasts in case no ships and 100% of ships use cold ironing					
Emissions	**1° year**	**5° year**	**10° year**	**15° year**	**20° year**
Nox (t)	€ 17,215,906.94	€ 86,079,534.71	€ 172,159,069.41	€ 258,238,604.12	€ 344,318,138.83
SO2 (t)	€ 4,679,129.92	€ 23,395,649.62	€ 46,791,299.24	€ 70,186,948.86	€ 93,582,598.48
PM (t)	€ 904,042.57	€ 4,520,212.85	€ 9,040,425.69	€ 13,560,638.54	€ 18,080,851.39
CO2	€ 623,752.27	€ 3,118,761.36	€ 6,237,522.72	€ 9,356,284.09	€ 12,475,045.45
Total	€ 23,422,831.71	€ 117,114,158.54	€ 234,228,317.07	€ 351,342,475.61	€ 468,456,634.14

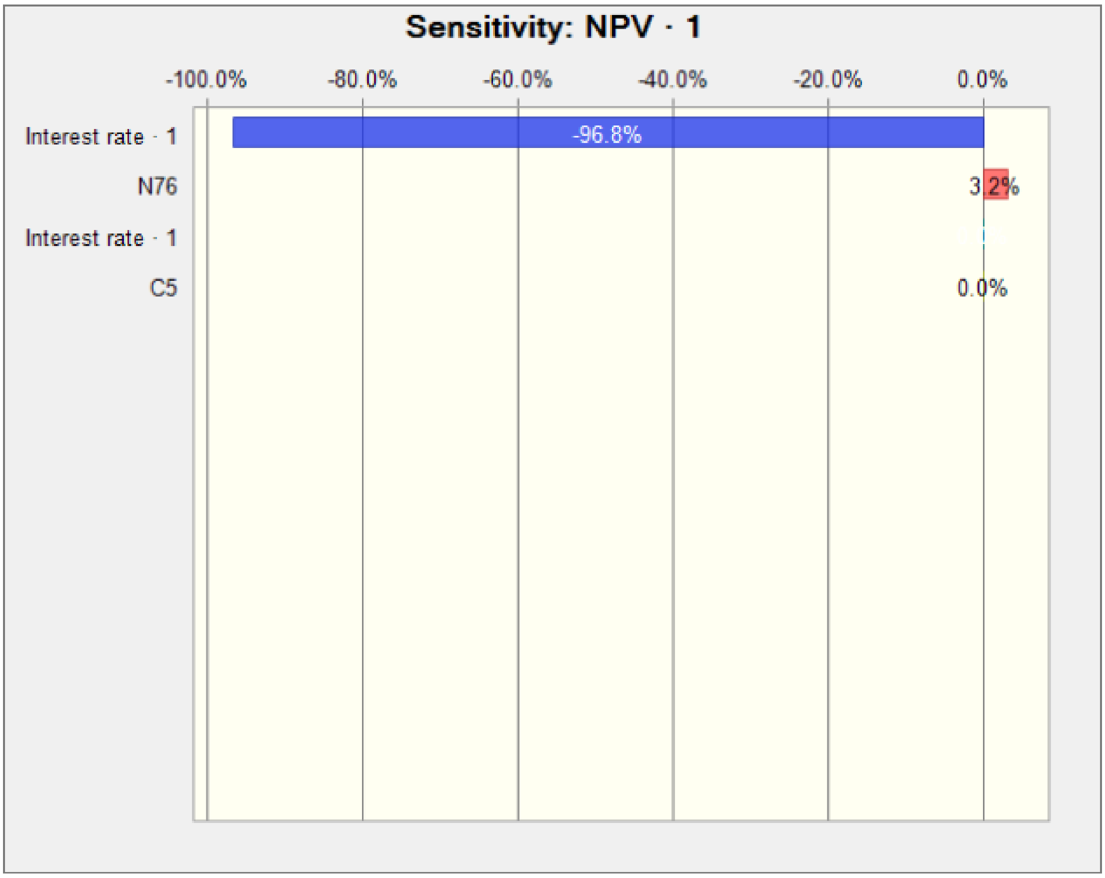
The aforementioned projections underscore significant financial benefits that can be derived from the deployment of the OPS system over a 20-year horizon. It should be noted that a typical OPS system has a lifespan of 20 years.

Table 17: Showing total health savings for over a 20 year period using social cost as the parameter.

Total health cost benefits - forecasts in case no ships and 50% of ships use cold ironing					
Emissions	**1° year**	**5° year**	**10° year**	**15° year**	**20° year**
Nox (t)	€ 8,607,953.47	€ 43,039,767.35	€ 86,079,534.71	€ 129,119,302.06	€ 172,159,069.41
SO2 (t)	€ 2,339,564.96	€ 11,697,824.81	€ 23,395,649.62	€ 35,093,474.43	€ 46,791,299.24
PM (t)	€ 452,021.28	€ 2,260,106.42	€ 4,520,212.85	€ 6,780,319.27	€ 9,040,425.69
CO2	€ 311,876.14	€ 1,559,380.68	€ 3,118,761.36	€ 4,678,142.04	€ 6,237,522.72
Total	€ 11,711,415.85	€ 58,557,079.27	€ 117,114,158.54	€ 175,671,237.80	€ 234,228,317.07

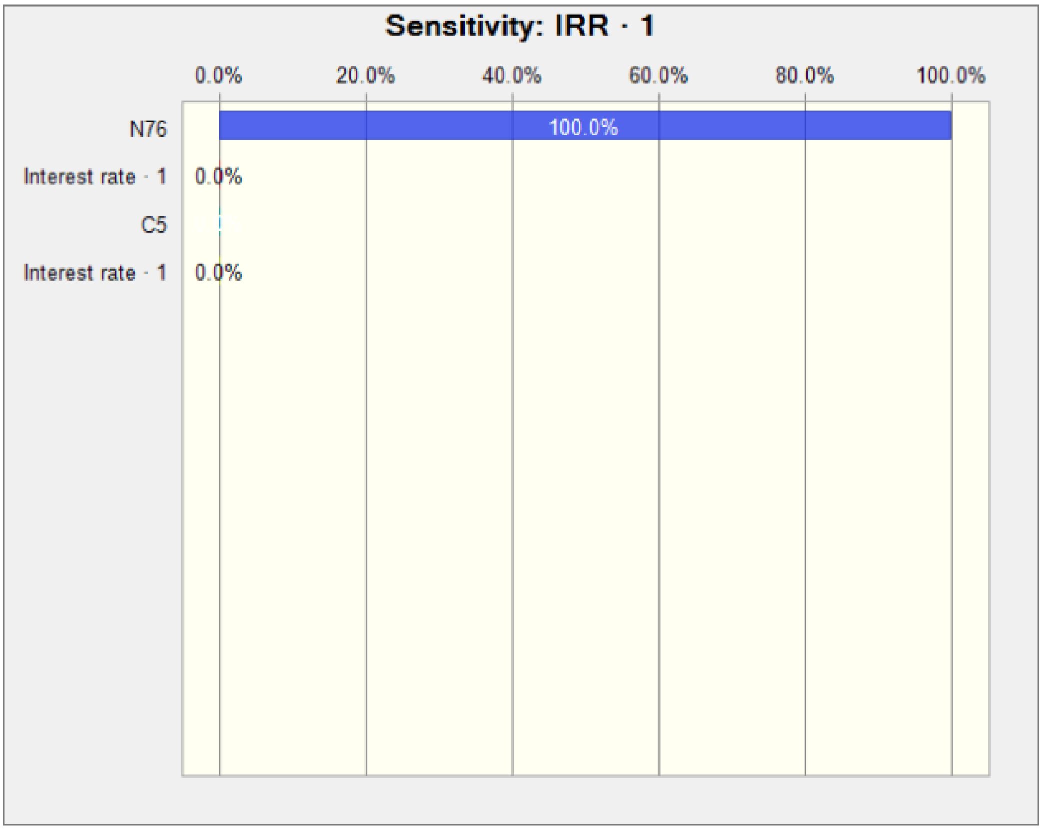
This project shows the potential savings forecasted and what it would mean for the state of Nigeria as it would not only ensure cleaner air for residents but also savings for the country and invariably mean development for the country as budget allocations could be diversified to other demanding sectors.

Figure 15: Showing how NPV reacts to a change in interest rate and capital outlay.



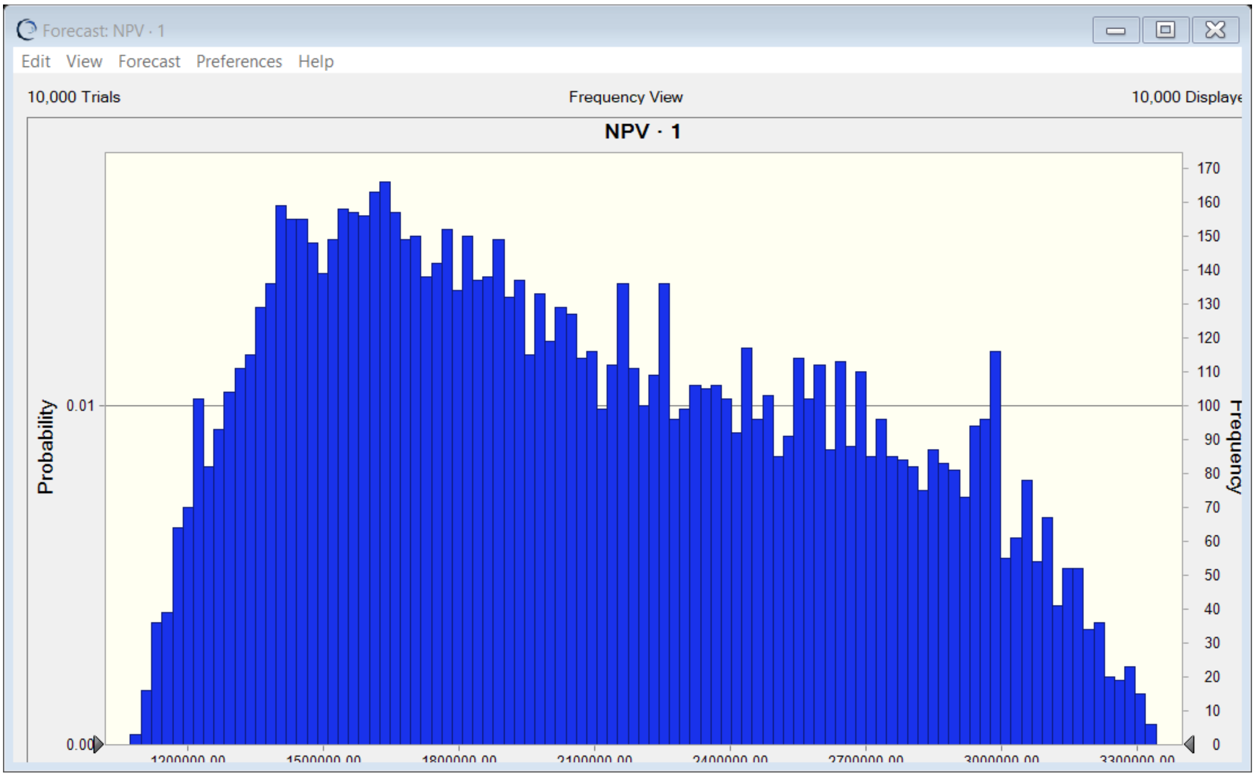
In the conducted sensitivity analysis of the NPV, it was observed that the NPV is particularly sensitive to fluctuations in the interest rate associated with the OPS implementation. Notably, the NPV demonstrated a pronounced reaction to an interest rate adjustment of 96.8%. Additionally, while the response to variations in the initial capital expenditure was less pronounced, there still existed a discernible sensitivity, with the NPV showing a response to a modification in the capital outlay by a margin of 3.2%. Such findings underscore the criticality of these variables in influencing the financial viability of the OPS project.

Figure 16: Showing how IRR responds to a change in Interest rate and Capital Outlay.



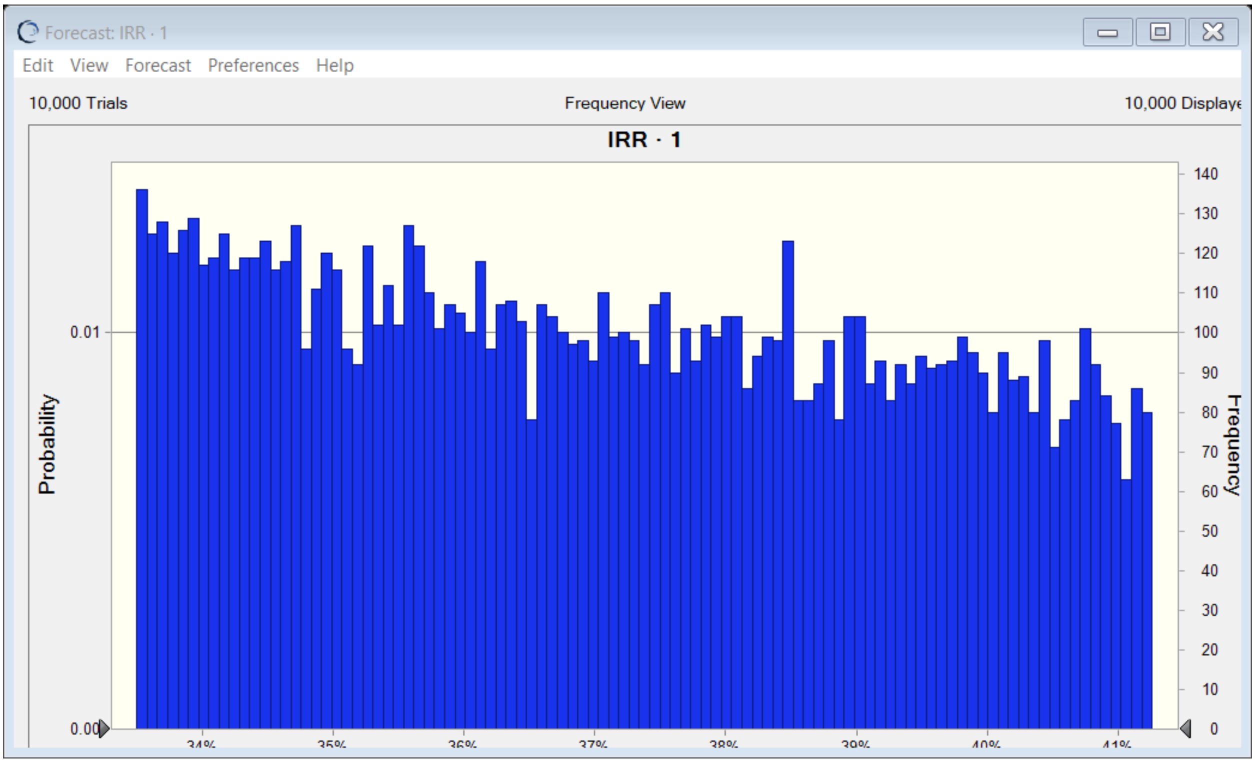
The project's Internal Rate of Return (IRR) demonstrates pronounced sensitivity to fluctuations in the capital expenditure. Notably, when there is a 100% alteration in the cost of initial investment, the IRR responds equivalently. This suggests that the financial attractiveness of the venture, gauged by the IRR, is directly contingent upon the precision of initial capital outlay estimations. Consequently, meticulous planning and exact budgeting become crucial in ensuring the prospective success and financial soundness of the project.

Figure 17: NPV probabilities at 10,000 trials



The net present value (NPV) for the OPS has been simulated over 10,000 trials. The NPV can range from $1,072,949.36 to $3,341,600.26, indicating the broad scope of potential outcomes. The most likely or "base case" value is $1,483,869.33. Furthermore, the standard error of the mean, which provides a measure of the accuracy of our estimation, is relatively small at $5,603.36. This suggests that the base case estimate is reliable and represents the central tendency of the 10,000 trials well.

Figure 18: IRR probabilities at 10,000 trials



Interpreted in simpler terms, the forecasted internal rate of return (IRR) has been calculated to be between 34% and 41%. The most probable or expected value within this range, known as the base case, is 37%. After simulating the forecast 10,000 times, the standard error (a measure of the accuracy of the estimate) of the mean value is found to be 0%, indicating a high confidence in the accuracy of this forecast.

6.0 Chapter 6: Swot Analysis

A SWOT analysis is a strategic planning tool that helps to identify their Strengths, Weaknesses, Opportunities, and Threats (Terrados et al., 2007).

Through the systematic categorization of advantageous and disadvantageous internal and external factors inside the four quadrants of a SWOT analysis grid, strategists can enhance their comprehension of how strengths can be effectively utilized to capitalize on emerging opportunities, while also recognizing how weaknesses may impede development or amplify threats (Helms & Nixon, 2010).

Table 18:Swot Analysis

	Virtues	Inhibitors
Internal	Strength	Weakness
External	Opportunities	Threats

In order to align shipping practices with the objectives set forth in the Paris Climate Agreement, it is imperative for the marine industry to achieve a 50% reduction in carbon dioxide (CO2) emissions by the year 2050.

Table 19: Swot Analysis of using an OPS system

Strengths	**Weaknesses**
• Reduction of local air pollution from ships (NOx, SOx and PM). • Reduction of Vibration and Noise. • Compliance with existent and future regulations. • Maturity of the OPS technology. • International Standards for OPS installations are available (ISO80005- 1:2019 HVSC and ISO 80005-3 LVSC). • Lower GHG emissions from ships at port. • Larger Auxiliary engine maintenance frequency. • Lower infrastructure cost compared • with other solutions (e.g. LNG).	• High investment cost for both port authority and ship-owners. • Long pay-back period. • Different frequencies (50/60Hz) for ships calling the port (need for frequency converters which are costly). • Technology available only on few ports.
Opportunities	**Threats**
• EU and government subsidies and incentives to port. • Incentives to ships complying with OPS technology. • New job opportunities. • Collaborations with ship-owners and other ports.	• No general regulations adopted so far. • Competence with other alternatives (LNG, Low-Sulphur Fuel, etc.). • Safety issues due to high voltage handling.

• Increasing customer demand to OPS facilities. • Tax reduction for electricity price.	• Specific training requirements for onboard crew and port operators. • Local power supply and extra loads. • Lack of available space at port.

6.1 Strengths

6.1.1 Reduction of Local Air Pollution from Ships (NOx, SOx, and PM)

OPS, has emerged as a compelling strategy to combat local air pollution from ships, particularly emissions like NOx, SOx, and PM.

The advantages of this approach extend beyond environmental preservation. Moreover, research has consistently demonstrated that particulate matter (PM) is a significant contributor to elevated rates of both mortality and morbidity. Approximately 3% of adult mortality can be attributed to cardiovascular and respiratory disorders, while approximately 5% of lung and trachea malignancies can be linked to particulate matter (PM) pollution (Ballini & Bozzo, 2015). Moreover, according to (Canepa et al., 2023) the primary ramifications of ship emissions encompass the acidification and eutrophication of the environment, leading to the generation of toxic substances that contribute to pulmonary infiltration, blood toxicity, cardiac insufficiency, and consequently, early mortality, OPS deployment diminishes the presence of acid rain precursors and improves visibility by curtailing the haze effect caused by PM emissions.

6.1.2 Reduction of Vibration and Noise Pollution as a Strength of Using OPS

OPS, the practice of providing ships with shore-based electrical power while docked, has been recognized not just for its environmental advantages, but also for significantly reducing noise and vibration disturbances in ports (Entec, 2005). For local communities and marine habitats adjacent to these ports, the benefits are immediate: residents enjoy an uplifted quality of life with fewer noise disruptions, while marine life, particularly those species dependent on sound for various activities, thrive in a less disturbed environment.

6.1.3 Compliance with Existent and Future Regulations

OPS is increasingly viewed not just as a method for environmental compliance but as a strategic asset for ports and shipping companies. One immediate advantage is the avoidance of potential penalties stemming from non-compliance with emission regulations. Yet, beyond mere compliance, forward-thinking entities are realizing the benefit of staying ahead of anticipated environmental mandates, thus positioning themselves as industry frontrunners rather than playing catch-up.

6.1.4 Maturity of the OPS Technology as a Strength for OPS

The maturity of OPS technology has brought about a suite of advantages that are reshaping the maritime landscape. Central to these is the reliability of such systems, having been refined and optimized over time, reducing operational hitches. This reliability dovetails with standardization, ensuring compatibility across various ships and ports, and providing a smoother, more uniform transition to shore power. Notably, as OPS technology becomes more ubiquitous, its costs decrease, owing to economies of scale, enhanced manufacturing processes, and heightened competition. This economic advantage is complemented by an expanding pool of experts familiar with OPS, ensuring skilled hands for its management.

6.1.5 International Standards for OPS Installations (ISO 80005-1:2019 HVSC and ISO 80005-3 LVSC) as a Strength of OPS

International standards, like the ISO 80005 series for OPS, bring transformative advantages to the global maritime industry. At their core, they ensure uniformity, ensuring that ports worldwide adopt and integrate OPS technologies with seamless compatibility. Such consistency eradicates ambiguity, providing clear-cut guidelines that minimize misunderstandings and potential conflicts among industry players. Furthermore, these standards emphasize paramount safety protocols, offering comprehensive procedures crafted from best practices and potential hazard evaluations.

6.1.6 Lower GHG Emissions from Ships at Port as a Strength of OPS

OPS, a burgeoning practice in the maritime industry, offers a sustainable solution to the pressing concerns of climate change. At the heart of its benefits is the significant reduction in greenhouse gas (GHG) emissions, which are pivotal contributors to global warming. By curbing these emissions, OPS aids in climate change mitigation and aligns with the broader goals set by global agreements like the Paris Agreement, enabling ports and the maritime sector to inch closer to their emission targets.

6.1.7 Larger Auxiliary Engine Maintenance Frequency as a Strength for OPS

Utilizing OPS in maritime operations extends beyond the obvious environmental benefits, tapping into a myriad of operational and economic advantages. One standout advantage is the tangible cost savings arising from extended maintenance intervals for auxiliary engines. Ships experience less wear and tear, leading to a prolonged engine lifespan and, consequently, better return on investment. This reduced reliance on auxiliary engines not only boosts operational efficiency by curtailing downtime but also diminishes the risk of unforeseen breakdowns.

Moreover, with fewer maintenance activities, the environmental and safety risks associated with such tasks—like potential oil leaks or safety incidents for crew members—see a marked decrease. In essence, OPS epitomizes how sustainable practices, while primarily environmental in intent, can ripple into areas of operational efficiency, cost savings, and crew well-being, reinforcing a progressive stance in maritime operations against the backdrop of a shifting global climate. This help reduce stakeholders investments and other associated costs (Zis, 2019).

6.1.8 6.1.7 Lower Infrastructure Cost Compared with LNG as a Strength for OPS

The primary factor contributing to cost reduction will be the utilization of electrical power as opposed to the more expensive low-sulphur gasoline (Zis, 2019).

OPS, presents a compelling alternative to LNG in maritime operations, particularly when considering infrastructure and cost. The flexibility of OPS infrastructure allows for easier scalability and adaptability based on port needs, without the complications and expenses tied to expanding or altering LNG facilities.

6.2 Weaknesses

6.2.1 High Investment Cost as a Weakness for OPS

OPS is a promising method for mitigating emissions in ports. However, its adoption comes with substantial financial considerations. Ports are faced with hefty initial outlays to establish essential infrastructure like electrical substations, transformers, and safety systems. Moreover, ships already in operation may require expensive retrofitting to accommodate OPS, potentially straining ship-owners' budgets. Some local electric grids might also be ill-equipped to cater to the augmented demand from ships, necessitating costly upgrades.

The cocktail of players and the attendant derived goal of considerable environmental benefits, its economic implications require a thoughtful approach (Winkel et al., 2016). To spur its adoption, mechanisms like financial incentives or innovative financing models might be necessary.

6.2.2 Long Pay-back Period as a Weakness for OPS

OPS presents significant environmental advantages for ports, yet its economic implications pose challenges. The initial establishment of OPS infrastructure necessitates a hefty investment in both port facilities and ship modifications. Furthermore, if a limited number of vessels are equipped for OPS, ports might initially find their costly infrastructure underutilized, thereby extending the time to recoup their investment. Additionally, the volatile maritime economy, combined with the potential opportunity costs of other investments, might further extend the pay-back horizon. In light of these challenges, enhancing OPS adoption might necessitate stronger financial incentives, innovative funding structures, or regulatory support to make the economic proposition more attractive.

6.2.3 Different Frequencies as a Weakness for OPS

The implementation of OPS in ports is not without its complexities, especially when faced with varying electrical frequencies across different regions

Integrating OPS in Nigerian ports, which operate on a 50Hz frequency, poses challenges when accommodating vessels from 60Hz regions. To bridge this gap, frequency converters are necessary, increasing costs and introducing operational complexities. These converters not only elevate the initial expenses of OPS but can also introduce energy inefficiencies (Ding et al., 2022). These converters can lead to energy inefficiencies and require added maintenance and space. The 50Hz-60Hz discrepancy might deter some international ships, emphasizing the need for Nigeria to adopt innovative or globally-consistent strategies to ensure efficient OPS adoption.

6.2.4 Limited Availability in Ports

The sporadic adoption of OPS in ports presents a myriad of challenges for the maritime sector. For ship-owners, the limited availability of OPS-equipped ports complicates the decision to retrofit vessels, given the diminished returns due to inconsistent usage across routes. This inconsistency also results in vessels juggling between OPS and onboard auxiliary engines, creating economic and operational inefficiencies. Furthermore, as a result of the challenging operational conditions associated with OPS equipment, there exists a significant susceptibility to a heightened probability of system malfunction, operational challenges arise, like the potential delays in switching power sources, and financial dilemmas about where to invest capital, especially when considering other pressing upgrades (Ding et al., 2022). Ultimately, for OPS to realize its full potential both economically and environmentally, a more cohesive and broader adoption strategy is essential in the maritime landscape.

6.3 Opportunities

6.3.1 Government Subsidies and Incentives as an Opportunity for OPS

Government incentives and subsidies have the potential to profoundly transform the adoption landscape of OPS in ports (Peng et al., 2023). Successful adoption in incentivized ports can serve as a beacon for others, reinforcing the feasibility of OPS. Moreover, such government backing can magnetize additional support from global environmental bodies and facilitate a more sustainable and diverse energy mix at ports. All in all, through strategic incentives, governments can accelerate the shift towards a more sustainable maritime sector.

6.3.2 Incentives to Ships Complying with OPS Technology

Financial incentives, such as reduced port fees for ships using OPS, can significantly influence ship owners' decisions, compelling them to retrofit existing vessels or ensure new ones are OPS-ready. This not only bolsters the return on investment for ship-owners but also positions ships as champions of environmental stewardship, a reputation that resonates with eco-conscious clients.

Moreover, the rising trend of Economic Social and Governance (ESG) investing means OPS-adapted ships might captivate green investors as this address port sustainability (Roko Glavinović et al., 2023). Ultimately, such incentives weave a web of economic and environmental benefits, solidifying the push for greener maritime practices.

6.3.3 New job opportunities of Implementing OPS Technology

In Lagos, Nigeria, the adoption of OPS—supplying ships with shoreside electrical power—blends environmental responsibility with economic growth. This initiative can boost the local economy by creating jobs: as Lagos ports upgrade their infrastructure for OPS, there's an immediate demand for engineers, electricians, and technicians for both installation and ongoing maintenance. The maritime sector's shift towards sustainable technologies further necessitates specialized training and education, offering potential growth in academic and training industries.

6.3.4 Increasing customer demand to OPS facilities

The rise in customer demand for OPS facilities presents a compelling opportunity to drive the widespread implementation of OPS in ports worldwide. As the maritime industry and the general public become more environmentally conscious, there's a growing preference for cleaner and more sustainable operations. This shift isn't just ideological; it's also driven by tangible benefits. When ships use OPS, they cut down on the emissions and noise generated by auxiliary engines, directly contributing to cleaner port cities and improved air quality. This makes ports more amenable to nearby residents and can enhance the overall reputation of cities or regions as being eco-friendly.

6.3.5 Collaborations with ship-owners and other ports

Collaborating with ship-owners and other ports emerges as a pivotal opportunity to expedite the adoption of OPS. By engaging directly with ship-owners, ports can align their infrastructure to meet the specific requirements and technical specifications of the majority of their docking vessels, ensuring seamless integration and utilization of OPS. Such collaboration can reduce hesitancy among ship-owners in retrofitting their vessels, as they're assured of compatibility and can see a clearer return on investment.

6.3.6 Increasing customer demand to OPS facilities

The rising customer demand for OPS facilities presents a significant opportunity for its broader implementation. As shipping lines, cargo owners, and other stakeholders increasingly prioritize sustainability, ports equipped with OPS can attract more vessels, boosting their traffic and economic viability. T

6.3.7 Tax reduction for electricity price

Tax reductions on electricity prices for OPS in Nigeria can drive its adoption. By lowering the operational costs of OPS, ports become more attractive to ship-owners, promoting sustainable shipping practices in the country. This financial incentive can accelerate Nigeria's transition to greener port operations, aligning with global maritime environmental standards.

6.4 Threats

6.4.1 No general regulations adopted so far

The lack of general regulations for OPS in Nigeria poses a threat to its adoption. Without a regulatory framework, there's uncertainty for stakeholders, potentially deterring investments in OPS infrastructure and hindering the nation's shift towards environmentally-friendly port operations.

6.4.2 Competence with other alternatives (LNG, Low-Sulphur Fuel, etc.)

The abundance of alternative solutions like LNG (Liquefied Natural Gas) and low-sulfur fuel in Nigeria presents a competitive threat to OPS. These alternatives, potentially seen as more adaptable or efficient, could divert investments away from OPS, impeding its establishment and growth in the country's ports even though the best of these alternatives will still result in more carbon footprint than the OPS.

6.4.3 Safety issues due to high voltage handling

High voltage handling in OPS poses safety risks in Nigeria. Potential electric shocks and equipment damage necessitate rigorous training and safety protocols. This threat emphasizes the need for Nigeria to invest in specialized training and infrastructure to safely implement OPS.

6.4.4 Specific training requirements for onboard crew and port operators.

The need for specific training for onboard crew and port operators presents a challenge to OPS adoption in Nigeria. Training demands additional resources and time, potentially slowing the transition and increasing costs for stakeholders.

6.4.5 Local power supply and extra loads

Local power supply limitations and added electrical loads in Nigeria pose threats to OPS implementation, potentially straining existing infrastructure and leading to reliability concerns for port operations. There is a deficiency in the local grid.

6.4.6 Lack of available space at port

In Nigeria, the lack of available space at ports poses a significant challenge for the integration of OPS systems. Ports are often densely packed areas, filled with cargo, equipment, and logistical setups necessary for day-to-day operations. The introduction of OPS would require the establishment of substations, transformers, connection equipment, and safety mechanisms. Setting up such infrastructure necessitates a significant amount of space, both for the equipment and to ensure safe operations (Spengler & Tovar, 2021). Given that many Nigerian ports are already operating at or near capacity, integrating OPS without compromising existing operations becomes complex.

Brief Swot Analysis of Blended Finance as it Relates to Clean Energy.

Strengths:

1. **Capital Synergy:** Through the amalgamation of both public and private financial instruments, blended finance augments the capital pool available for clean energy initiatives.
2. **Risk Diversification:** The collective nature of this financial model dilutes risk exposure for individual stakeholders.

Weaknesses:

1. **Operational Intricacy:** The coordination of multifaceted contributors renders the decision-making matrix more intricate.
2. **Objective Disparity:** The potential exists for incongruities in the strategic objectives among varied investor classes, leading to potential discord.

Opportunities:

1. **Project Amplification:** Enhanced capital availability can capacitate the execution of broader and more transformative clean energy endeavors.
2. **Investment Catalysis:** Blended finance has the potential to allure reticent investors, given its demonstrative commitment and risk-alleviating attributes.

Threats:

1. **Potential Over-dependence:** An unwarranted reliance on blended finance could potentially inhibit naturalized investments from the private sector.
2. **Regulatory Intricacies:** The diverse nature of funding constituents may lead to challenges in regulatory adherence and compliance.

7.0 Chapter 7: Recommendations and Conclusions

A discernible relationship exists between a nation's Gross Domestic Product (GDP) and its trade patterns. Maritime transport serves as a paramount conduit in facilitating trade for numerous countries, with Nigeria being a prime example. As Nigeria endeavors to augment its GDP, maritime transport is poised to be at the forefront of this economic progression. However, this could inadvertently escalate environmental pollution in port cities, taking Lagos as a salient case. Notwithstanding that the Apapa port operates under the landlord model supervised by the Nigerian Ports Authority (NPA), the concessionaires act as collaborative stakeholders in the port's operations.

In the quest for the maritime sector to attain decarbonization by the IMO's 2050 target, an amalgamation of strategies will be pivotal. OPS represents a readily available solution with immediate environmental benefits.

From an ecological standpoint, deploying OPS would translate to a marked improvement in air quality within the port and its adjacent regions. This would concomitantly lead to a palpable decrease in societal costs, especially given that approximately 70% of respiratory ailments in port cities can be attributed to emissions. Furthermore, entities such as ship owners, shipping corporations, and associated ship management firms stand to gain considerably, as there would be a notable decrease in bunker costs during hoteling at berths, alongside diminished engine maintenance expenses due to reduced wear.

The NPA shoulders the mandate of optimizing operational costs for both ship owners and terminal operators, all the while generating revenue for the Federal Government of Nigeria. Hence, the integration of OPS emerges as a compelling priority, given its potential to fulfill diverse objectives and yield substantial benefits. While there may be contention regarding the feasibility of OPS owing to its significant capital expenditure and operational costs, such arguments are effectively countered by the prospective adoption of the Blended Finance model.

The Blended Finance adoption de-risks this project and makes it viable as this serves as hedging means for investors

The previously done analysis in chapter 5 shows Nigeria electricity is well below bunker prices and this makes it attractive for an OPS.

The Nigeria system is structured to give Pioneer status for this OPS as it’s the first of its kind in Nigeria and thus it would naturally be exempted from taxes for the first 2 years, and the next 3 years after subject to approval of an application showing the social benefits accruing from the Business project.

Previous studies have recommended that OPS shouldn’t be rushed for implementation even with the obvious benefits to all stakeholders because of the lead time involved in the project delivery as the berth involved would be closed for operations and this would affect the revenues that is to be generated from the port and that ports should require subsidies from the government to help cushion the effects of the capex but this is what the Blended Finance model approach caters to.

Recommendations

i. Leveraging Advanced Technological Solutions for the Application of a 'Just-In-Time' Approach to Container Vessel Arrivals: Efficient scheduling and synchronization of vessel arrivals can significantly reduce idling and associated emissions, thus optimizing port operations.

ii. Advocating for the Integration of Smart Grid Systems to Facilitate Renewable Energy Production via Solar Technologies: This approach underscores the imperative of adopting sustainable energy sources to enhance port energy efficiency and reduce carbon footprints.

iii. Envisioning a Shift towards Harnessing Wind and Ocean Energy Technologies: Beyond immediate energy needs, this strategy positions the port as an avant-garde energy nexus. By tapping into these renewable sources, the port not only diversifies its energy portfolio but also contributes significantly to the mitigation of health risks associated with traditional emission sources.

iv. Championing Electrification Initiatives Across Port Activities: Transitioning from conventional to electrically powered operations can substantially curtail greenhouse gas emissions and improve air quality in the port vicinity.

v. Exploring Blended Finance Mechanisms to Bolster Clean Energy Production: By combining public, private, and philanthropic finances, there's an enhanced capacity to raise substantial funds for sustainable energy projects, furthering the port's commitment to environmental stewardship.

vi. More Research and Development endeavors be carried out in the areas of Onshore Power systems.

vii. Technological transfers be encouraged between global north and the global south.

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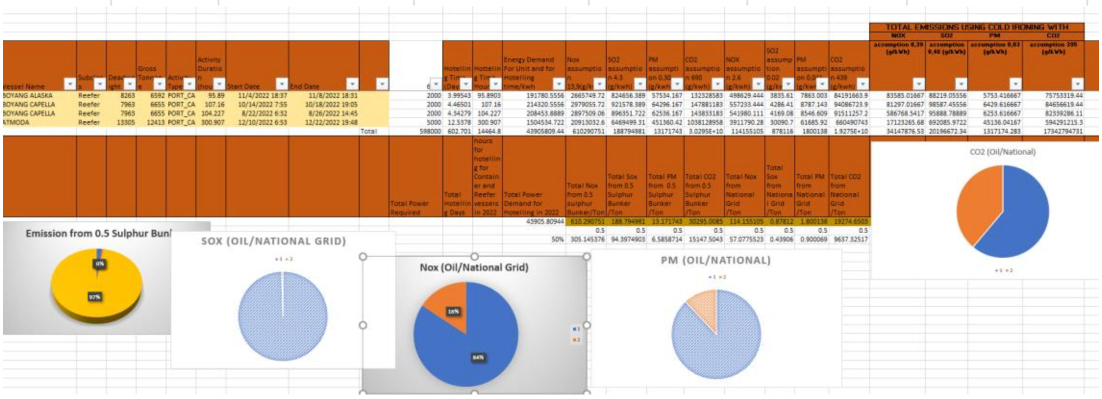
Appendices

	NPV for OPS system					
	Interest rat	0.185	Tax	30%		
	Year	Net Cash Flow ($)	CCF	18.5% D.R	DCF	CDCF
CAPEX	0	€ (1,725,000.00)	€ (1,725,000.00)	1	€ (1,725,000.00)	€ (1,725,000.00)
OPEX	1	€ 644,130.00	€ (1,080,870.00)	1.185	€ 543,569.62	€ (1,181,430.38)
	2	€ 644,130.00	€ (436,740.00)	1.404225	€ 458,708.54	€ (722,721.84)
	3	€ 644,130.00	€ 207,390.00	1.664006625	€ 387,095.81	€ (335,626.02)
	4	€ 644,130.00	€ 851,520.00	1.971847851	€ 326,663.13	€ (8,962.89)
	5	€ 644,130.00	€ 1,495,650.00	2.336639703	€ 275,665.09	€ 266,702.20
	6	€ 450,891.00	€ 1,946,541.00	2.768918048	€ 162,840.14	€ 429,542.34
	7	€ 450,891.00	€ 2,397,432.00	3.281167887	€ 137,417.84	€ 566,960.18
	8	€ 450,891.00	€ 2,848,323.00	3.888183946	€ 115,964.42	€ 682,924.60
	9	€ 450,891.00	€ 3,299,214.00	4.607497976	€ 97,860.27	€ 780,784.87
	10	€ 450,891.00	€ 3,750,105.00	5.459885102	€ 82,582.51	€ 863,367.38
	11	€ 450,891.00	€ 4,200,996.00	6.469963845	€ 69,689.88	€ 933,057.26
	12	€ 450,891.00	€ 4,651,887.00	7.666907157	€ 58,810.02	€ 991,867.28
	13	€ 450,891.00	€ 5,102,778.00	9.085284981	€ 49,628.71	€ 1,041,496.00
	14	€ 450,891.00	€ 5,553,669.00	10.7660627	€ 41,880.77	€ 1,083,376.77
	15	€ 450,891.00	€ 6,004,560.00	12.7577843	€ 35,342.42	€ 1,118,719.19
	PBP	3.32	years			
	NPV	1118719.19				
	IRR	34%				



MARGINAL DAMAGES POLLUTING AGENT FOR TON OF		
Nox	$	34,700.00
SO2	$	24,900.00
PM2	$	79,500.00
CO2	$	56.600

SCENARIO 1 - 100% SHIPS USE COLD IRONING FOR THE YEAR 2022 - electricity production as per				
	Nox (t)	SO2 (t)	PM (t)	CO2
Health costs deriving from emissions from ships with auxiliary engines running	€ 21,177,089.07	€ 4,700,995.02	€ 1,047,153.56	€ 1,714,697.48
Health costs deriving from Emissions Ships using cold ironing	€ 3,961,182.13	€ 21,865.09	€ 143,110.99	€ 1,090,945.21
DIFFERENCE	€ 17,215,906.94	€ 4,679,129.92	€ 904,042.57	€ 623,752.27
% VARIATION	81.3%	99.5%	86.3%	36.4%
Total health cost savings by using cold ironing				€ 23,422,831.71

SCENARIO 2 - 50% SHIPS USE COLD IRONING FOR THE YEAR 2022 - electricity production as per				
	Nox (t)	SO2 (t)	PM (t)	CO2
Health costs deriving from emissions from ships with auxiliary engines running	€ 10,588,544.53	€ 2,350,497.51	€ 523,576.78	€ 857,348.74
Health costs deriving from Emissions Ships using cold ironing	€ 1,980,591.06	€ 10,932.55	€ 71,555.49	€ 545,472.60
DIFFERENCE	€ 8,607,953.47	€ 2,339,564.96	€ 452,021.28	€ 311,876.14
% VARIATION	81.3%	99.5%	86.3%	36.4%
Total health cost savings by using cold ironing				€ 11,711,415.85

Total health cost benefits - forecasts in case no ships and 100% of ships use cold ironing					
Emissions	**1° year**	**5° year**	**10° year**	**15° year**	**20° year**
Nox (t)	€ 17,215,906.94	€ 86,079,534.71	€ 172,159,069.41	€ 258,238,604.12	€ 344,318,138.83
SO2 (t)	€ 4,679,129.92	€ 23,395,649.62	€ 46,791,299.24	€ 70,186,948.86	€ 93,582,598.48
PM (t)	€ 904,042.57	€ 4,520,212.85	€ 9,040,425.69	€ 13,560,638.54	€ 18,080,851.39
CO2	€ 623,752.27	€ 3,118,761.36	€ 6,237,522.72	€ 9,356,284.09	€ 12,475,045.45
Total	€ 23,422,831.71	€ 117,114,158.54	€ 234,228,317.07	€ 351,342,475.61	€ 468,456,634.14

Total health cost benefits - forecasts in case no ships and 50% of ships use cold ironing					
Emissions	**1° year**	**5° year**	**10° year**	**15° year**	**20° year**
Nox (t)	€ 8,607,953.47	€ 43,039,767.35	€ 86,079,534.71	€ 129,119,302.06	€ 172,159,069.41
SO2 (t)	€ 2,339,564.96	€ 11,697,824.81	€ 23,395,649.62	€ 35,093,474.43	€ 46,791,299.24
PM (t)	€ 452,021.28	€ 2,260,106.42	€ 4,520,212.85	€ 6,780,319.27	€ 9,040,425.69
CO2	€ 311,876.14	€ 1,559,380.68	€ 3,118,761.36	€ 4,678,142.04	€ 6,237,522.72
Total	€ 11,711,415.85	€ 58,557,079.27	€ 117,114,158.54	€ 175,671,237.80	€ 234,228,317.07

INFRASTRUCTURE COSTS			€ 12,840,000.00	€ 25,680,000.00
SAVINGS USING ELECTRICITY			€ 94,431.03	€ 188,862.06
HEALTH COSTS SAVINGS (1 YEAR)			€ 11,711,415.85	€ 23,422,831.71
			€ 11,805,846.89	€ 23,611,693.77

CALCULATION OF BENEFITS IF 50% Capacity was installed		
BENEFITS	1 YEAR	20 years (discounted)
HEALTH COSTS SAVINGS (1 YEAR)	€ 11,711,415.85	
COSTS		
INFRASTRUCTURE COSTS	€ 12,840,000.00	
NPV		

CALCULATION OF BENEFITS IF 100% Capacity was installed		
BENEFITS	1 YEAR	20 years (discounted)
HEALTH COSTS SAVINGS (1 YEAR)	€ 23,422,831.71	
COSTS		
INFRASTRUCTURE COSTS	€ 25,680,000.00	
NPV		

AVERAGE HOTELLING AT BERTH FOR CALL	92.13263	hours
AVERAGE ENERGY DEMAND PER CALL	279.6548	Mw/h per visit
AVERAGE ENERGY DEMAND PER SHIP	585.4108	Mw/h per ship
AVERAGE VISIT NUMBER FOR SHIP /YEAR	2.093333	times

Hotelling phase emission factors using Shore side power			
g / kWh of electric power			
Nox (g/kWh)	SO2 (g/kWh)	PM (g/kWh)	CO2 (g/kWh)
2.6	0.02	0.041	439

Reduction of Emissions from using National Grid to Auxilliary Engines			
g / kWh of electric power			
Nox (g/kWh)	SO2 (g/kWh)	PM (g/kWh)	CO2 (g/kWh)
11.3	4.28	0.259	251

Hotelling phase emission factors with using Shoreside Power			
g / kWh of electric power			
Nox (g/kWh)	SO2 (g/kWh)	PM (g/kWh)	CO2 (g/kWh)
114.1551046	0.878116189	1.800138187	19274.65035

Conversion of Power Demand to Liters of Fuel

43905809.44		
9.9633		
4406753.731	317286.2686	
4406.753731	3190489.701	

Hotelling phase emission factors with auxiliary engines using fuel with 0.5% sulfur				
g / kWh of electric power				
Nox [g/kWh]	SOx [g/kWh]	PM [g/kWh]	CO2 [g/kWh]	Total
34.7	24.9	79.5	0.0566	
34700	24900	79500	56.6	
610.2907513	188.7949806	13.17174283	30295.00852	
21,177,089.07	4,700,995.02	1,047,153.56	1,714,697.48	28,639,935.12

Hotelling phase emission factors using shoreside from National Grid				
g / kWh of electric power				
Nox [g/kWh]	SO2 [g/kWh]	PM [g/kWh]	CO2 [g/kWh]	Total
34.7	24.9	79.5	0.0566	
34700	24900	79500	56.6	
114.1551046	0.878116189	1.800138187	19274.65035	
3,961,182.13	21,865.09	143,110.99	1,090,945.21	5,217,103.42

Price per kw of MDO used		
Kw per liter od MDO		9.963
Price per ton of MDO	$	724.00
Kw per ton od MDO		9963
Price per kw of MDO used	$	0.073
Price per Kw of Power from National Grid		67
Coverting to Dollar		980
Price in Dollar	$	0.068

	Social Cost
Social Cost of using AE with 0.5 sulp	28,639,935.12
Social Cost of using Shoreside Powe	5,217,103.42
Savings	23,422,831.71

Euros to Dollar Conversion
23,422,831.71
1.07
$ 25,062,429.93

Total Kwh		43905809.44
Kw per Litre		9.963
Litres of MDO 0.5 Bunker		4406886.424
Tons of Bunker for total kwh		4406.886424
Price of Bunker	$	3,190,585.77
Price of Electricity for Ops	$	3,001,723.71
Savings from using Ops	$	188,862.06
50% Capacity	$	94,431.03
Euros to Dollar		1.07
50% of OPS capacity cost in Euros		12,000,000
		12,840,000.00
100% Capacity cost in Euros		24,000,000
		25,680,000.00

Nox [g/kWh]	SOx [g/kWh]	PM [g/kWh]	CO2 [g/kWh]	Total
34.7	24.9	79.5	0.0566	
34,700.00	24,900.00	79,500.00	56.60	
34.14787653	20.19667234	1.317174283	17342.79473	
1,184,931.32	502,897.14	104,715.36	981,602.18	########

	Social Cost
Social Cost of using AE with 0.5 sulp	28,639,935.12
Social Cost of using Entec data from	2,774,145.99
Savings	25,865,789.13

Euros to Dollar Conversion
25,865,789.13
1.07
$ 27,676,394.37

Savings from using Entec data fr		27,676,394.37
Savings from using the National (	$	25,062,429.93
Savings	$	2,613,964.44

Conversion of Kilowatts to Marine Diesel Oil

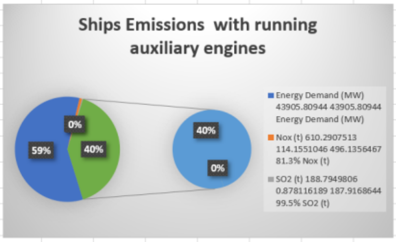
Total Kwh	43905809.44
Kw per Litre	9.963
Litres of MDO 0.5 Bunker	4406886.424
Tons of Bunker for total kwh	4406.886424

Cost of Bunker

Total Kwh	43905809.44
Kw per Litre	9.963
Litres of MDO 0.5 Bunker	4406886.424
Tons of Bunker for total kwh	4406.886424
Price of Bunker	$ 3,190,585.77
Exchage rate of Dollar to Euro	1.07
Price of Bunker in Euro	3,413,926.77

SCENARIO 1 - 100% SHIPS USE COLD IRONING FOR THE YEAR 2022 Electricity production as per average emission factors for Nigeria

	Energy Demand (MW)	Nox (t)	SO2 (t)	PM (t)	CO2 (t)
Ships Emissions with running auxiliary engines	43905.80944	610.2907513	188.7949806	13.17174283	30295.00852
Ship Emissions using cold ironing	43905.80944	114.1551046	0.878116189	1.800138187	19274.65035
DIFFERENCE		496.1356467	187.9168644	11.37160465	11020.35817
% VARIATION		81.3%	99.5%	86.3%	36.4%



SCENARIO 2 - 100% SHIPS USE COLD IRONING FOR THE YEAR 2022 - production of electricity as per the hypothesized energy mix

	Energy Demand (MW)	Nox (t)	SO2 (t)	PM (t)	CO2 (t)
Ships Emissions with running auxiliary engines	43905.80944	610.2907513	188.7949806	13.17174283	30295.00852
Ship Emissions using cold ironing	43905.80944	34.14787653	20.19667234	1.317174283	17342.79473
DIFFERENCE		576.1428747	168.5983083	11.85456855	12952.21379
% VARIATION		94%	89%	90%	43%

INVESTMENT COSTS

	Input		Yearly costs (€)
B	**General info**		
	interest rate	10%	
	depreciation (years)	20	
C	**investment costs terminal**		
	high voltage connection from grid (including transformer) (€)	4,000,000	
	freq. converter (€)	500,000	
	cable installation (€)	225,000	451,350
	total investments (€)	4,725,000	
	maintenance, contract and electricity transport costs (15%) (€)	250,750	
D	**investment costs ships**		
	transformer (€)	300,000	
	main switchboard, control panel (€)	100,000	4,003,257
	cabling (€)	3,000	
	cable reel system (€)	152,000	
	total investments (€)	555,000	

OPERATIONAL COSTS

	Input		Yearly costs (€)
E	**Electricity costs**		
	Electricity price (€/ kWh)	0.04	
	tax (€/ kWh)	-	3,020,000
	Consumption (kW)	7,500	
	Saved maintenance		
	Maintenance per engine (€/ h)	-2	-144460.0
	number of engines	3	
F	**TOTAL COSTS (€)**		**14,234,964**

POLLUTION

	Input		pollution units
G	Electricity source	EU mix	
	Pollutants	**Emissions (ton)**	**Pollution units**
	CO2	79002.0	
	NOx	73.0	73,002
	PM	0.7	8,550
	SO2	103.0	220,425
	Total		316,030

INVESTMENT COSTS

Input terminal		Yearly costs (€)
General info		
no investments		
investment costs terminal		
no investments		
investment costs ships		
no investments		

OPERATIONAL COSTS

Input terminal		Yearly costs (€)
Fuel costs		
Diesel (USD/ton)	724	23,728,770
Consumption (ton/h)	4.7	
ETS costs		
ETS CO2 price	0	0
		23,728,770

POLLUTION

Input		pollution units
Fuel	Diesel	
Pollutants	**Emissions (ton)**	**Pollution units**
CO2	158506.5	
NOx	3376.0	3,376,774
PM	104.5	1,334,010
SO2	240.5	546,242
Total		5,257,034

H	Total yearly costs (€)	9,493,806-
	cost effectiveness (€ / pollution uni	1.9-

I	Emission reductions electricity	
	NOx	98%
	PM	99%
	SO2	58%
	CO2	50%

Price Determination for Ship Owners		At 10% Markup	At 20% Markup	At 30% Markup	At 40% Markup
		0.10	0.20	30%	0.40
Amount paid to Utility Company	€ 9,028,800.00	€ 9,931,680.00	€ 10,834,560.00	€ 11,737,440.00	€ 12,640,320.00
Power Demand in kw	43905809.44	43905809.44	43905809.44	43905809.44	43905809.44
Proposed Margin	€ 0.21	0.23	0.25	€ 0.27	0.29

Amount from using AE	€ 23,728,769.86	0.02
		902,880.00
Unit cost of kW from AE	€ 0.54	644,130.00

Pricing Difference	€ 0.02
Margin	€ 902,880.00
Maintenance Cost	€ (258,750.00)
Inflow	€ 644,130.00

OPS calculation tool

Manual

Below, a stepwise manual for working with the tool is provided. The capital letters indicated can be found in the left-hand side of the tool.

A	Under "General information", data can be entered on how frequently ships are berthed and for how long. These data are needed to calculate operational costs and emission changes.
B	Depreciation period and interest rate affect annual costs, with higher interest rates and shorter depreciation periods leading to higher annual costs.
C	Here the investments costs at the terminal can be filled in. The tool distinguishes various cost categories, which are summed to yield the total investment costs. Annual costs are calculated using the interest rate and depreciation period. Investment costs are not relevant for the auxiliary engines, as these are vital outside the ports.
D	In this section the shipside investments costs are filled in. A range of cost categories are listed, which are summed to yield the total investment costs. Annual costs are calculated using the interest rate and depreciation period.
E	The operational costs depend on fuel and electricity consumption levels, fuel and electricity prices and electricity taxes. From these data, annual costs are calculated. Savings on auxiliary engine maintenance costs can be filled in here, with negative costs standing for benefits. The total benefits are calculated from the number of hours at berth, as input to the General information section. There is an option to calculate with a CO_2 price in advance.This option enables simulation of the influence of inclusion of the Maritime industry in the EU ETS on the cost effectiveness of OPS.
F	The total annual costs are calculated by summing the various cost categories under B to F. The costs or benefits accruing from using OPS can be calculated by comparing the 'auxiliary engine costs' with the 'OPS costs' (row 65), the outcome of which is presented in Box I.
G	The emission benefits are calculated by using emission factors from the data section and total annual consumption figures. Total annual consumption is calculated on the basis of the ships' consumption and the number and duration of port calls. The emission benefits can be found by comparing the figures in rows 76-80. The type of fuel can be changed from diesel to HFO here, as well as the energy source used for power generation (by clicking on a pull-down menu).
H	The total annual costs can be calculated by subtracting the 'auxiliary engine costs' from the 'OPS costs'. Negative costs mean that OPS yields a financial benefit. The cost effectiveness is expressed in Euro per unit of pollution. Pollution units are used to sum the various air pollutants, with SO_2 and PM being judged to be 2.2 and 12.8 times more harmful on the basis of a study by AEA Technology (2005).
I	For each pollutant the relative emission reduction is calculated using the figures in rows 76-80.

Note: the basic data can be changed in the 'data' sheet. These basic data include emission factors for fuel burning and power consumption.