ASSESSMENT OF CARBON(IV) OXIDE EMISSION AND MANAGEMENT OF SELECTED INDUSTRIES IN AGBARA INDUSTRIAL ESTATE, OGUN STATE, NIGERIA

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Declaration

I declare that the work in this dissertation entitled "Assessment of carbon(iv) oxide emission and management of selected industries in Agbara industrial estate, Ogun state, Nigeria" has been performed by me in the Department of Geography and Environmental Management. The information derived from the literature has been duly acknowledged in the text and list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other Institution.

Muhammed Kabeer IBRAHIM

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Signature **Date**

Certification

This dissertation entitled "ASSESSMENT OF CARBON(IV) OXIDE EMISSION AND MANAGEMENT OF SELECTED INDUSTRIES IN AGBARA INDUSTRIAL ESTATE, OGUN STATE, NIGERIA" by Muhammed Kabeer IBRAHIM, meets the regulations governing the award of the degree of Master of Science in Environmental Management of the Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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Dedication

This work is dedicated to my Mum, Mrs. Ibrahim Olushola Afsat, may Allah (SWT) grant her a long and prosperous life (Ameen).

Acknowledgement

First and foremost, I have to appreciate the Almighty Allah the most Beneficent, the most Merciful for His unparalleled sufficiency and mercy upon me.

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Abstract

This study was aimed at contributing to the efforts directed at managing Carbon(iv) oxide, CO_2 emission by assessing the CO_2 emissions and management strategies in the Nigerian manufacturing industries using some selected industries at Agbara Industrial Estate, Ogun state. The main objectives of the study are to determine the amount of CO_2 emitted from the stationery sources of the selected industries in the study area between the periods of June 2015 to May 2016, and to compare this amount with the inclusion threshold i.e. the maximum allowable amount of CO_2 emission of various emission management programmes around the world. The study also checked for the performance of each of the industry as regards CO_2 management best practices. The industries were grouped into different industrial strata according to Manufacturers Association of Nigeria industrial classification, after which one industry was picked per stratum. Five industries namely; Industry N, Industry G, Industry Q, Industry D and Industry P were randomly selected using dip in the basket method from a total of seventeen industries for the study. The identity of the industries was concealed due to security reasons. The use of documented emission factors in measuring CO_2 emission was the adopted method in this work. Twelve months' fuel consumption records of each emission source from each selected industry was collated and examined, this was then used to calculate the CO_2 emission for each emission source by multiplying the monthly volume/mass (as the case may be) of the fossil fuel combusted with the appropriate emission factor. The performance of each of the industry as regards CO_2 management best practices was assessed using a GHG best management practice checklist adapted from that of the World Wildlife Fund which was used for their Low Carbon Manufacturing Programme. Results showed that Industry N emitted a total of 7714.65 tones of CO_2, Industry G emitted 45,055.45 tones of CO_2, Industry Q emitted 8,200.94 tones of CO_2, Industry D emitted 53,195.54 tones of CO_2 and Industry P emitted 49,247.78 tones of CO_2

during the studied period. These figures are larger than the inclusion threshold of many carbon management programmes around the world. Statistical significance findings showed that natural gas fuel and natural gas combusting stationery equipments are the major contributors of the CO_2 emitted in the assessed industries. Also all the industries practice a poor CO_2 emission management. The study concluded that a significant amount of CO_2 was emitted by the assessed industries and these were majorly contributed by natural gas fuel combustion, the industries also practice a very poor CO_2 emission management. It is therefore recommended that industries should focus their attention on natural gas and natural gas combusting sources for their emission management activities, environmental regulators should develop an emission standards/programme where a cap or a predetermined maximum allowable amount of CO_2 is allocated to industries and there is need for consideration of the other greenhouse gas emissions in subsequent studies.

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Acronyms and Abbreviations

AGO:	Automated gas oil
°C:	degree centigrade
CO_2:	Carbon(iv) Oxide
CO_2-eq:	Carbon(iv) oxide equivalents
CFCs:	Chlorofluorocarbons
$GtCO_2$-eq:	Giga tones of carbon(iv) oxide equivalents
GHG:	Greenhouse gas
Gt yr^{-1}:	Giga tones per year
$GgCO_2$-eq:	Giga gram of carbon(iv) oxide equivalents
KVA:	Kilo volt amperes
LPG:	Liquefied petroleum gas
m:	meters
mm yr^{-1}:	millimeter per year
N_2O:	Nitrogen(iv) oxide
O_3:	Ozone
PFCs:	Per fluorocarbons
ppm:	Part per million
SF_6:	Sulphur fluoride
%:	Percentage
EJ:	Primary energy
UNFCCC:	United Nation Framework Convention on Climate Change
IPCC:	Intergovernmental Panel on Climate Change
MAN:	Manufacturers Association of Nigeria
SME:	Small and Medium Scale Enterprises
CH_4:	Methane
HFC:	Hydro fluorocarbons
CCS:	Carbon Capture and Storage
IEA:	International Energy Agency

WWF:	World Wild Life Fund
TPES:	Total Primary Energy Supply
WRI:	World Resource Institute
GDP:	Gross Domestic Product

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Warming of the climate system is an undisputable fact of the 21st century (Intergovernmental Panel on Climate Change, IPCC, 2001). This average increase in global temperature is unequivocal, as it is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (IPCC, 2007). Each of the last three decades has been successively warmer at the Earth's surface than any preceding decades since 1850, and the period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere (IPCC, 2014). The globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 (0.65 to 1.06) °C over the period 1880 to 2012 (IPCC, 2014).

This observed increase in global average temperatures and the associated climate change has been attributed with a very high level of confidence and strong scientific consensus to the increase in anthropogenic greenhouse gases (GHGs) concentrations which is largely due to fossil fuel combustion and to a smaller extent due to changes in land use and deforestation (United Nations, 2013). These gases have been proven to be capable of absorbing infrared radiation as it is reflected from the earth's surface, therefore acting like a blanket, trapping heat, and keeping the earth warm, a process known as the greenhouse effect (World Resource Institute, WRI, 2006).The Kyoto protocol identified six of these gases that affect the energy balance of the global atmosphere and needs to be urgently addressed, they include, carbon dioxide (CO_2) the most prevalent, followed by methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and Sulphur hexafluoride (SF_6) in a decreasing order of prevalence (WRI, 2006).

Anthropogenic emissions of CO_2 constitute by far, the largest part of the emissions of greenhouse gases and of these CO_2 emissions, those that are produced from fuel combustion make up the great majority and almost all may be directly estimated from combustion activities (Simmons, 2010). Since the beginning of the Industrial revolution, the levels of GHGs in the atmosphere have been observed to have grown rapidly as a result of human activities, particularly due to the burning of fossil fuels like coal, oil, and natural gas as an energy source (WRI, 2006). IPCC (2014) reported that between 1750 and 2011, the cumulative anthropogenic CO_2 emissions to the atmosphere were 2040 ± 310 $GtCO_2$ which by far exceeded the natural range over the last 650,000 years and of which half of this emissions occurred in the last 40 years. They revealed that total anthropogenic GHG emissions continuously increase from 1970 to 2010 with larger absolute increases between 2000 and 2010.

In Nigeria, according to the second national communication of the country greenhouse gas inventory to the united nation framework convention on climate change in 2014 by the Federal Ministry of Environment, Nigeria contributed about 214.21 million tones of CO_2 to the atmosphere in the year 2000 and as expected, the energy sector (fuel combustion and fugitive emissions) contributed the largest proportion (53.6%) of these emissions (Federal Ministry of Environment, 2015). Within this sector, combustion of fossil for powering industrial processes was identified as a major contributor to the atmospheric CO_2.

Globally, the industrial sector is the third largest source of man-made CO_2 emissions after electricity/heat and transportation sector (International Energy Agency IEA, 2012). This sector produced 20% of fossil fuel related CO_2 emissions in 2010. The industrial sector consists of manufacturing, construction, mining, and agriculture. Manufacturing is the largest of the 4 and can be broken down into 5 main categories: paper, food, petroleum refineries, chemicals, and metal/mineral products. These categories account for the vast majority of the fossil fuel use and CO_2 emissions by this sector. Manufacturing and industrial processes all combine to produce large amounts of each type of greenhouse gas but specifically large amounts of CO_2. This is because many manufacturing facilities directly use fossil fuels to create heat and steam needed at various stages of production. For example factories in the cement industry, have to heat up limestone to 1450°C to turn it into cement, which is done by burning fossil fuels to create the required heat (IEA, 2012). In Nigeria, an industrial activity is a cause of a substantial amount of CO_2 emission. According to the latest national GHG inventory communication to the United Nation Convention on Climate Change (UNFCCC) by the Federal Ministry of Environment in 2014, energy-related activities have the dominant share of GHG emissions in Nigeria and industrial activities has been identified has a major contributor of these emissions (Federal Ministry of Environment, 2014).

1.2 Statement of the Research Problem

The review of the global greenhouse gas emission in the last three decades by IPCC (2007) as reported in their fourth assessment report showed that there is a continuous and rapid increase in atmospheric concentrations of the long-lived GHG gases especially CO_2 and that the predominant source of the increase is from the combustion of fossil fuels. It has also been established that the sustained increase in CO_2 emission is interfering and will continue to interfere with the natural climate system thereby increasing the risk of permanent environmental damage and grave socio-economic consequences.

Unfortunately, Nigeria contributes a significant amount of these gases to the atmosphere and energy-related activities have the dominant share of the emission of these gases. Within the energy sector, industrial activities especially manufacturing have been identified as a major contributor of CO_2 (Federal Ministry of Environment, 2014). For example, the energy sector (fuel combustion and fugitive emissions) contributed the largest proportion (70%) to direct GHG emissions in Nigeria in year 2000 (latest year for which data were submitted to the UNFCCC as part of the national GHG inventory communication) of which CO_2 was the largest contributor at a percentage of 74% of the total energy sector emissions. The manufacturing and construction sub-sector accounted for 12.6% of the energy emissions in the same year after gas flaring and transportation subsector (Federal Ministry of Environment, 2014). Meanwhile, Nigeria's vision for the industrial sector especially manufacturing is a technologically driven and globally competitive sector, it is expected that this sector will account for a larger percentage of the fossil fuel energy demand in the nearest future. Consequently, this will have serious implication on climate change in the very near future.

1.3 Justification of the Study

Industrial sector is a major focus towards sustainable management of future GHG emissions in Nigeria. As a result, there is need for detailed, systematic and regular assessment of CO_2 emission in this sector of the economy, so that the best emission reduction opportunities can be identified. There is also need for implementation of effective emission management strategies in this sector so that the sector will develop in a clean and climate friendly manner.

However, in light of prior reviews of literatures concerning CO_2 emission and management practices observed in the manufacturing sector, there are a lot of gaps that are needed to be filled and to the best of the researcher's knowledge, no empirical studies exist on the assessment of CO_2 emission and management in the Nigerian manufacturing sector with a view of discerning the nature and management strategies of CO_2 emission in the sector. The closest related literatures include the work of Edeoja and Edeoja (2015) who evaluated the management of carbon emissions in the Nigerian construction industry by measuring the amount of CO_2 being emitted from constructional activities within some selected organizations, the work of Anomohanra (2011) who investigated the amount of CO_2 emission released from the consumption of petroleum product in Nigeria between 1999 and 2009, the work of Nwaichi and Uzazobona (2011) who delve into exploring the level and distribution of CO_2 and other associated potential contaminants in the Niger Delta and the work of Okhimamhe and Okelola (2013) in a study of the assessment of the levels of atmospheric carbon dioxide emission at road junctions in three major cities in the southeast of Niger State in Nigeria. The idea thereof of this study is to fill this gap in research. This study therefore seeks to contribute to the efforts directed to managing GHG emission by assessing the CO_2 emissions and management strategies observed in the Nigerian manufacturing sector by means of some selected industries at Agbara industrial estate, Ogun state.

Consequently, the information derived from the result of the study will first and foremost enable the likes of the selected manufacturing industries to identify opportunities to reduce emissions and draw up a long-term plan to manage their company's impact on climate change. This study will also provides information that will be useful in monitoring and managing emissions of manufacturing industries in the study area and elsewhere in the country by the relevant agencies (National Environmental Standards and Regulation Enforcement Agency, NESREA, Department of Petroleum Resources, DPR, Federal and States Ministries of Environment e.t.c.). The result of the study will also be useful in the development of emission abatement policies aimed at accelerating energy efficiency improvement in the industrial sector in Nigeria. Also the information derived from the study will provide an intelligent basis for accounting for the emissions due to manufacturing industries activity in the country. The study will also reveal the provisions that are put in place and currently observed for CO_2 emission monitoring and management in the Nigeria manufacturing industry which will allow for its scrutiny as to how adequate and effective it is. This study will therefore, ultimately contribute to the global efforts directed at managing GHG emissions.

This study then seeks to answer the following questions.

i. What are the sources of CO_2 emission of the selected industries in the study area?
ii. What are the activity data of the identified emission sources?
iii. What is the amount of CO_2 emitted from the identified emission sources?
iv. How close is each selected industry to CO_2 management best practices?

1.4 Aim and Objectives

The aim of this study is to assess the CO_2 emission and management in Agbara industrial estate, Ogun State, while the specific objectives are to:

i. identify CO_2 emission sources of the selected industries in the study area.
ii. identify the activity data of the identified emission sources.
iii. determine the amount of CO_2 emitted from the identified emission sources.
iv. compare the management practices of each selected industry to CO_2 management best practices.

1.5 Scope of the Study

The study covered CO_2 emissions from five carefully selected industries in the study area. The study focused on direct/scope 1 emission that are from stationary combustion that is, combustion of fossil fuels in stationary equipment such as boilers, furnaces, generators, burners, turbines, heaters, incinerators, engines, flares, etc. and the emission estimation covered a period of 12 months (June 2015-May 2016).

CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

This chapter presents some of the key concepts regarding GHGs emissions with emphasis on CO_2 by industrial activities that are applicable to this work. It also presents relevant literatures that were reviewed concerning the focus of the study.

2.2 Conceptual Framework

2.2.1 The industrial sector and carbon emission

Globally, and in most countries, CO_2 accounts for more than 90% of CO_2-eq GHG emissions from the industrial sector (International Energy Agency IEA, 2010). These CO_2 emissions arise from three sources: (i) the use of fossil fuels for energy, either directly by industry for heat and power generation or indirectly in the generation of purchased electricity and steam; (ii) non-energy uses of fossil fuels in chemical processing and metal smelting; and (iii) non-fossil fuel sources, for example cement and lime manufacture (US Environmental Protection Agency, 2009). Industrial processes also emit other GHGs, for example,

i. N_2O is emitted as a byproduct of adipic acid, nitric acid and caprolactam production. It is also emitted from during agricultural and industrial activities as well as combustion of fuel and solid waste.

ii. HFC-23 is emitted as a byproduct of HCFC-22 production, a refrigerant, and also used in fluoroplastics manufacture and industrial processes.

iii. PFCs are emitted as byproducts of aluminium smelting and in semiconductor manufacture.

iv. SF_6 is emitted in the manufacture, use and, decommissioning of gas insulated electrical switchgear, during the production of flat screen panels and semiconductors, from magnesium die casting and other industrial applications.

v. CH_4 is emitted as a byproduct of some chemical processes and

vi. CH_4 and N_2O can be emitted by food industry waste streams (WRI, 2006).

Nearly third of the world's energy consumption and 36% of CO_2 emissions are attributable to the industrial sector. The large primary materials industries; chemical, petrochemicals, iron and steel, cement, paper and pulp, and other minerals and metals account for more than two-thirds of this amount (Allwood *et al*., 2010). The industrial sector is highly energy intensive; the total final energy consumption of the sector worldwide was around 127 EJ in 2007. This is approximately 40% of global final energy used and 70% was from fossil fuels (IEA, 2008). With currently available technologies, the options for replacing fossil fuels or switching to less carbon intensive fossil fuels are limited and they will likely remain the predominant source of energy in industry at least for the remainder of this century (McKinsey and Company, 2009). Around 40% of global CO_2 emissions arise from industrial processes; either directly (emitted at the point of use of a fuel) or indirectly (emissions emitted prior to the use of the fuel or electricity, e.g. emissions from the generation of electricity or refining of crude oil). In 2007, total global direct emissions from industry were 7.6Gt of CO_2 and currently, indirect CO_2 emissions make up around 32% of total industrial CO_2 emissions (Allwood *et al*., 2010). Indirect CO_2 emissions can be addressed by the decarbonisation of the electricity sector. In addition, demand for electricity can be reduced through improved efficiency of various electrical appliances such as refrigerators and motor-driven equipment such as fans, compressors and pumps. Assuming a largely decarbonised power sector in the future, there is an argument for switching to production processes that use electricity, in order to reduce consumption of fossil fuels in industry (IEA-International Emission Trading Scheme IETS, 2006).

2.2.2 Energy use and greenhouse gases emissions

The Fifth Assessment Report from the IPCC (Working Group I) states that human influence on the increase in global average temperature is clear (IPCC, 2013). Among the many human activities that produce greenhouse gases, the use of energy represents by far the largest source of emissions. Smaller shares correspond to agriculture, producing mainly methane and N_2O from domestic livestock and rice cultivation, and to industrial processes not related to energy, producing mainly fluorinated gases and N_2O (IEA, 2015). Within the energy sector, CO_2 resulting from the oxidation of carbon in fuels during combustion dominates total GHG emissions. CO_2 emissions from energy represent over three quarters of the anthropogenic GHG emissions at a global scale (IPCC, 2006).

Increasing demand for energy comes from worldwide economic growth and development (Lejeune and Hanschmidt, 2009). Global total primary energy supply (TPES) increased by almost 150% between 1971 and 2013 mainly relying on fossil fuels. Despite the growth of non-fossil energy (such as nuclear and hydropower) that are considered as non-emitting, the share of fossil fuels within the world energy supply is relatively unchanged over the past 42 years. In 2013, fossil sources accounted for 82% of the global TPES (Hodges and Hawkes, 2010). Growing world energy demand from fossil fuels plays a key role in the upward trend in CO_2 emissions. Since the Industrial revolution, annual CO_2 emissions from fuel combustion have dramatically increased from near zero to over 32 $GtCO_2$ in 2013 (Hodges and Hawkes, 2010).

As regards emissions by fuel, even though coal represented 29% of the world TPES in 2013, it accounted for 46% of the global CO_2 emissions due to its heavy carbon content per unit of energy released. Compared to gas, coal is nearly twice as emission intensive on average. From the late 1980s until the early 2000s, coal and oil were each responsible for approximately 40% of global CO_2 emissions, with emissions from oil generally exceeding those from coal by a few percentage points (IEA, 2008). In 2013, CO_2 emissions from the combustion of coal increased by 3.4% to 14.8 $GtCO_2$. Currently, coal fills much of the growing energy demand of those developing countries (such as China and India) where energy-intensive industrial production is growing rapidly and large coal reserves exist with limited reserves of other energy sources (Florin and Fennell, 2010).

Furthermore, two sectors produced nearly two-thirds of global CO_2 emissions: electricity and heat generation, by far the largest, which accounted for 42%, while transport accounted for 23% (Ekins and Etheridge, 2006). Generation of electricity and heat worldwide relies heavily on coal, the most carbon-intensive fossil fuel. Countries such as Australia, China, India, Poland and South Africa produce over two-thirds of their electricity and heat through the combustion of coal (Ekins and Etheridge, 2006).

2.2.3 The flow of GHG due to human demand for energy services

The Sankey diagram in Figure 2.1 provides a conceptual illustration of the flow of GHG emission via the chain of technology and system required to deliver final services that are triggered by human demands. The diagram is based on the breakdown of total global anthropogenic GHG emissions in 2010 as reported by Bajželj *et al*., (2013). The figure shows how human demand for energy services, on the left, is provided by economic sectors, through the use of equipment in which devices create heat or work from final energy. The width of each line

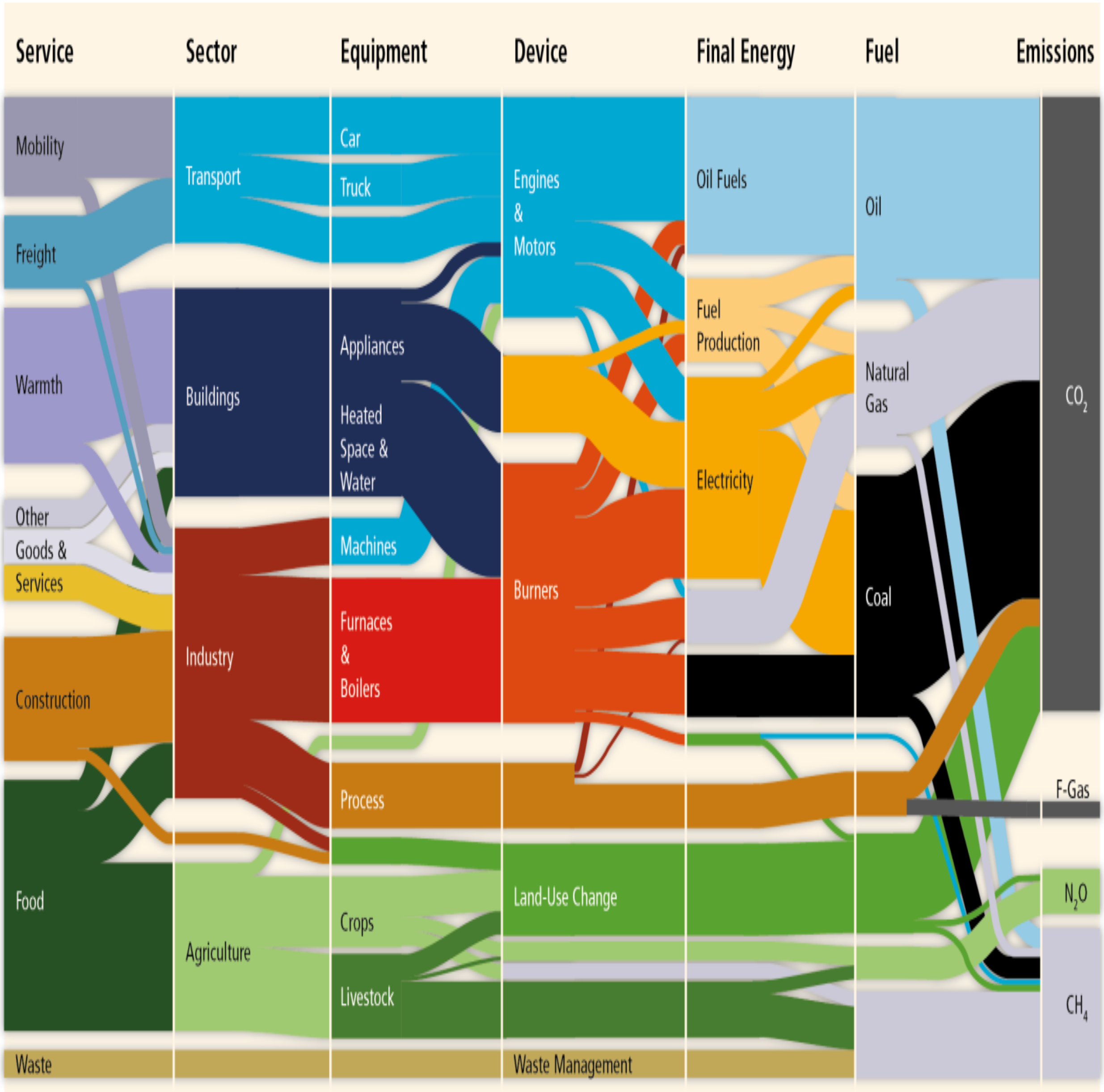

Figure 2.1 The system boundaries of various service sectors and demonstrating how global anthropogenic emissions arose from the chain of technologies and systems required to deliver final services triggered by human demand

Source: Fischedick *et al*., (2014)

is proportional to GHG emissions released, and the sum of these widths along any vertical slice through the diagram is the same. Combustion of carbon-based fuels leads to the release of GHG emissions as shown on the right. CO_2 emission represents the largest GHG emission which is predominantly as a result of combustion of carbon based fuels like coal, oil and natural gas. Other GHG emitted by fulfilling human needs includes methane, fluorinated gases (F gases) and Nitrous oxides which are mainly generated via food production in agriculture and waste management.

2.2.4 Carbon emission management

Carbon management is the concept of managing carbon dioxide emissions from anthropogenic activities so as to minimize its effects on global climate (Edeoja and Edeoja 2015). Addressing the threat posed by carbon emissions ultimately require behavioral changes in the global consumption and utilization of energy especially fossil fuels (Edeoja and Edeoja, 2015). Tackling carbon emission is a local issue that will depend on the individual country's emissions status and vulnerability to climate change. It will therefore require management strategies that are locally adaptive since sources like energy (availability, alternatives or mixes and demand), carbon sinks and other factors vary widely globally. In developed and developing countries, the largest sources of carbon dioxide are from fossil fuel while in less-developed countries, most of the carbon emissions are from sources such as fossil fuel consumption in the transport sector, industrial sector, deforestation, gas flaring as a result of oil exploration and land use (Federal Ministry of Environment, 2014). Managing carbon emissions successfully will require the development of different types of options which will include the followings:

i. Greater efficiency in the production and use of energy.
ii. Greater use of renewable energy technologies.

iii. Technologies for removing carbon from hydrocarbon fuels and sequestering it away from the atmosphere.

iv. A mixture of behavioural and operational changes in forestry, agricultural, industrial and land use practices and

v. Other approaPPches, some of which are currently very controversial, such as nuclear power and carbon capture and storage (Caldeira *et al*., 2004).

2.2.5 Mitigation opportunities for GHG in the industrial sector.

Fischedick *et al*., (2014) in the contribution of working group III to the fifth assessment report of the IPCC provided a simplified conceptual expression that defines six options for GHG mitigation within the industrial sector. The expression was depicted by

$$G = G/E \times E/M \times M/P \times P/S \times S \qquad (2.1)$$

They explained that G is the GHG emissions of the industrial sector within a specified time period (usually one year), E is industrial sector energy consumption and M is the total global production of materials in that period. P is stock of products created from these materials (including both consumables and durables added to existing stocks), and S is the services delivered in the time period through use of those products.

They elaborated further that G/E is the emissions intensity of the sector expressed as a ratio to the energy used. The reduction in G/E is referred to as emissions efficiency for the energy inputs and the processes. The GHG emissions of industry arise largely from energy use (directly from combusting fossil fuels, and indirectly through purchasing electricity and steam), but emissions also arise from industrial chemical reactions. In particular, producing cement, chemicals, and non-ferrous metals leads to the inevitable release of significant ‘process emissions’ regardless of energy supply. The improvement of industrial emission efficiency via for example switching to non-fossil fuel electricity supply, or applying carbon capture and storage technology is a significant potential opportunity for GHG emission reduction in the industrial sector.

E/M is the energy intensity and its reduction is the goal of energy efficiency. Approximately three quarters of industrial energy use is required to create materials from ores, oil or biomass, with the remaining quarter used in the downstream; manufacturing and construction sectors that convert materials to products. There are many options for energy efficiency improvement and significant potential to reduce the gap between actual energy use and the best practice in the industrial sector. In industry, energy efficiency opportunities can be found within sector specific processes as well as in systems such as steam systems, process heating systems (furnaces and boilers), and electric motor systems (e.g., pumps, fans, air compressor, refrigerators, material handling). Opportunities to improve heat management can be found in better heat exchange between hot and cold gases and fluids, improved insulation, capture and use of heat in hot products, and use of exhaust heat for electricity generation or as an input to lower temperature processes. The energy required can also in some cases (particularly for metals and paper) be reduced by production from recycled scrap, and can be further reduced by material re-use, or by exchange of waste heat and exchange of by-products between sectors.

M/P is the material intensity of the sector. The amount of material required to create a product and maintain the stock of a product depends both on the design of the product and on the scrap discarded during its production. Both can be reduced by material efficiency. Reducing yield losses in materials production, manufacturing, and construction as well as re-using old material would significantly improve material efficiency in manufacturing existing products.

P/S is the product-service intensity and its reduction is referred to as product-service efficiency. They explained that the level of service provided by a product depends on its intensity of use. For consumables (e.g. food or detergent) that are used within the accounting period in which they are produced, service is provided solely by the production within that period. For durables that last for longer than the accounting period (e.g. clothing), services are provided by the stock of products in current use. In this case P is the flow of material required to replace retiring products and to meet demand for increases in total stock. Thus for consumables, P/S can be reduced by more precise use (for example using only recommended doses of detergents or applying fertilizer precisely) while for durables, P/S can be reduced both by using durable products for longer and by using them more intensively.

Finally, S is the total global demand for service and it is a function of population, wealth, lifestyle, and the whole social system of expectations and aspirations. If the total demand for service were to decrease, it would lead to a reduction in industrial emissions, and this is referred to as demand reduction.

2.3 Literature Review

2.3.1 Main sources of CO_2 emissions

There are both natural and human sources of CO_2 emissions. Natural sources include decomposition, ocean release and respiration. Human sources come from activities like cement production, deforestation as well as the burning of fossil fuels like coal, oil and natural gas. Due to human activities, the atmospheric concentration of CO_2 has been rising extensively since the Industrial revolution and has now reached dangerous levels not seen in the last 3 million years (Le Quere *et al.*, 2011). Human sources of CO_2 emissions are much smaller than natural emissions but they have upset the natural balance that existed for many thousands of years before the influence of humans. This is because natural sinks remove around the same quantity of CO_2 from the atmosphere than are produced by natural sources (Denman *et al*., 2007). This had kept CO_2 levels balanced and in a safe range. But human sources of emissions have upset the natural balance by adding extra CO_2 to the atmosphere without removing any (Renewable Energy, 2017).

2.3.1.1 *Human sources*

Since the Industrial Revolution, human sources of CO_2 emissions have been growing. Human activities such as the burning of oil, coal and gas, as well as deforestation are the primary cause of the increased CO_2 concentrations in the atmosphere (Renewable Energy, 2017). 87% of all human-produced CO_2 emissions come from the burning of fossil fuels like coal, natural gas and oil. The remainder results from the clearing of forests and other land use changes (9%), as well as some industrial processes such as cement manufacturing (4%) (Le Quere *et al*., 2011).

Fossil fuel combustion/use:

The largest human source of CO_2 emissions is from the combustion of fossil fuels. This produces 87% of human CO_2 emissions. Burning these fuels release energy which is most commonly turned into heat, electricity or power for transportation. Some examples of where they are used are in power plants, cars, planes and industrial facilities (Renewable Energy, 2017). In 2011, fossil fuel use created 33.2 billion tons of CO_2 emissions worldwide (Le Quere *et al*., 2011). The 3 types of fossil fuels that are used the most are coal, natural gas and oil. Coal is responsible for 43% of CO_2 emissions from fuel combustion, 36% is produced by oil and 20% from natural gas (International Energy Agency IEA, 2012). Coal is the most carbon intensive fossil fuel. For every ton of coal burned, approximately 2.5 tons of CO_2e are produced (UK Department for Environment, Food and Rural Affairs, 2014). Of all the different types of fossil fuels, coal produces the most CO_2. Because of this and its high rate of use, coal is the largest fossil fuel source of CO_2 emissions. Coal represents one-third of fossil fuels' share of world total primary energy supply but is responsible for 43% of CO_2 emissions from fossil fuel use.

The three main economic sectors that use fossil fuels are: electricity/heat, transportation and industry. The first two sectors, electricity/heat and transportation, produced nearly two-thirds of global CO_2 emissions in 2010 (IEA, 2012).

Electricity/Heat sector:

Electricity and heat generation is the economic sector that produces the largest amount of man-made CO_2 emissions. This sector produced 41% of fossil fuel related CO_2 emissions in 2010. Around the world, this sector relies heavily on coal, the most carbon-intensive of fossil fuels, explaining this sector giant carbon footprint (IEA, 2012). Almost all industrialized nations get the majority of their electricity from the combustion of fossil fuels (around 60-90%).

The industrial, residential and commercial sectors are the main users of electricity covering 92% of usage. Industry is the largest consumer of the three because certain manufacturing processes are very energy intensive. Specifically, the production of chemicals, iron/steel, cement, aluminum as well as pulp and paper accounts for the great majority of industrial electricity use. The residential and commercial sectors are also heavily reliant on electricity for meeting their energy needs, particularly for lighting, heating, air conditioning and appliances (Renewable Energy, 2017).

Transportation sector:

The transportation sector is the second largest source of anthropogenic CO_2 emissions. Transporting goods and people around the world produced 22% of fossil fuel related CO_2 emissions in 2010 (IEA, 2012). This sector is very energy intensive and it uses petroleum based fuels (gasoline, diesel, kerosene, etc.) almost exclusively to meet those needs. Since the 1990s, transport related emissions have grown rapidly, increasing by 45% in less than 2 decades (International Transport Forum ITF, 2014).

Road transport accounts for 72% of this sector's CO_2 emissions (IEA, 2012). Automobiles, freight and light-duty trucks are the main sources of emissions for the whole transport sector and emissions from these three have steadily grown since 1990. Apart from road vehicles, the other important sources of emissions for this sector are marine shipping and global aviation.

Marine shipping produces 14% of all transport CO_2 emissions. While there are a lot less ships than road vehicles used in the transportation sector, ships burn the dirtiest fuel on the market, a fuel that is so unrefined that it can be solid enough to be walked across at room temperature (Harrould-Kolieb and Ellycia, 2008). Because of this, marine shipping is responsible for over 1 billion tons of CO_2 emissions (Harrould-Kolieb *et al.*, 2010).This is more than the annual emissions of several industrialized countries (Germany, South Korea, Canada, UK, etc.) and this sector continues to grow rapidly.

Global aviation accounts for 11% of all transport CO_2 emissions. International flights create about 62% of these emissions with domestic flights representing the remaining 38% (International Civil Aviation Organization ICAO, 2010). Over the last 10 years, aviation has been one of the fastest growing sources of CO_2 emissions (Smale *et al.*, 2012). Aviation is also the most carbon-intensive form of transportation, so its growth comes with a heavy impact on climate change.

Industrial sector:

The industrial sector is the third largest source of man-made CO_2 emissions. This sector produced 20% of fossil fuel related CO_2 emissions in 2010 (IEA, 2012). The industrial sector consists of manufacturing, construction, mining, and agriculture. Manufacturing is the largest of the 4 and can be broken down into 5 main categories: paper, food, petroleum refineries, chemicals, and metal/mineral products. These categories account for the vast majority of the fossil fuel use and CO_2 emissions by this sector.

Manufacturing and industrial processes all combine to produce large amounts of each type of greenhouse gas but specifically large amounts of CO_2. This is because many manufacturing facilities directly use fossil fuels to create heat and steam needed at various stages of production. For example factories in the cement industry, have to heat up limestone to 1450°C to turn it into cement, which is done by burning fossil fuels to create the required heat (Renewable Energy, 2017).

Land use changes:

Land use changes are a substantial source of CO_2 emissions globally, accounting for 9% of human CO_2 emissions and contributed 3.3 billion tons of CO_2 emissions in 2011 (Le Quere *et al* ., 2011). Land use changes are when the natural environment is converted into areas for human use like agricultural land or settlements. From 1850 to 2000, land use and land use change released an estimated 396-690 billion tons of CO_2 to the atmosphere, or about 28-40% of total anthropogenic CO_2 emissions (Houghton, 2010).

Deforestation has been responsible for the great majority of these emissions. Deforestation is the permanent removal of standing forests and is the most important type of land use change because its impact on greenhouse gas emissions. Forests in many areas have been cleared for timber or burned for conversion to farms and pastures. When forested land is cleared, large quantities of greenhouse gases are released and this ends up increasing CO_2 levels (Renewable Energy, 2017).

Industrial processes:

There are many industrial processes that produce significant amounts of CO_2 emissions as a byproduct of chemical reactions needed in their production process. Industrial processes account for 4% of human CO_2 emissions and contributed 1.7 billion tons of CO_2 emissions in 2011(Le Quere *et al* ., 2011).

Many industrial processes emit CO_2 directly through fossil fuel combustion as well indirectly through the use of electricity that is generated using fossil fuels. But there are four main types of industrial process that are a significant source of CO_2 emissions: the production and consumption of mineral products such as cement, the production of metals such as iron and steel, as well as the production of chemicals and petrochemical products (Renewable Energy, 2017).

Cement production produces the most amount of CO_2 amongst all industrial processes. To create the main ingredient in cement, calcium oxide, limestone is chemically transformed by heating it to very high temperatures. This process produces large quantities of CO_2 as a byproduct of the chemical reaction. So much so that making 1000 kg of cement produces nearly 900 kg of CO_2 (Ba-Shammak *et al*., 2008).

Steel production is another industrial process that is an important source of CO_2 emissions. To create steel, iron is melted and refined to lower its carbon content. This process uses oxygen to combine with the carbon in iron which creates CO_2. On average, 1.9 tons of CO_2 are emitted for every ton of steel produced (World Steel Association WSA, 2011).

Fossil fuels are used to create chemicals and petrochemical products which lead to CO_2 emissions. The industrial production of ammonia and hydrogen most often uses natural gas or other fossil fuels as a starting base, creating CO_2 in the process. Petrochemical products like plastics, solvents, and lubricants are created using petroleum. These products evaporate, dissolve, or wear out over time releasing even more CO_2 during the product's life (Renewable Energy, 2017).

2.3.1.2 *Natural sources*

Apart from being created by human activities, CO_2 is also released into the atmosphere by natural processes. The Earth's oceans, soil, plants, animals and volcanoes are all natural sources of CO_2 emissions. Human sources of CO_2 are much smaller than natural emissions but they upset the balance in the carbon cycle that existed before the Industrial Revolution. The amount of CO_2 produced by natural sources is completely offset by natural carbon sinks and has been for thousands of years. Before the influence of humans, CO_2 levels were quite steady because of this natural balance (Denman *et al*., 2007). 42.84 % of all naturally produced CO_2 emissions come from ocean-atmosphere exchange. Other important natural sources include plant and animal respiration (28.56%) as well as soil respiration and decomposition (28.56%) (Denman *et al*., 2007). A minor amount is also created by volcanic eruptions (0.03%) (Gerlach and Terry, 2011).

Ocean-atmosphere exchange:

The largest natural source of CO_2 emissions is from ocean-atmosphere exchange. This produces 42.84% of natural CO_2 emissions. The oceans contain dissolved CO_2, which is released into the air at the sea surface. Annually this process creates about 330 billion tons of CO_2 emissions (Denman *et al*., 2007).

Plant and animal respiration:

An important natural source of CO_2 is plant and animal respiration, which accounts for 28.56% of natural emissions. CO_2 is a byproduct of the chemical reaction that plants and animals use to produce the energy they need. Annually this process creates about 220 billion tons of CO_2 emissions (Denman *et al*., 2007).

Soil respiration and decomposition:

Another important natural source of CO_2 is soil respiration and decomposition, which accounts for 28.56% of natural emissions. Many organisms that live in the Earth's soil use respiration to produce energy. Amongst them are decomposers who break down dead organic material. Both of these processes release CO_2 as a byproduct. Annually these soil organisms create about 220 billion tons of CO_2 emissions (Denman *et al*., 2007).

Volcanic eruptions:

A minor amount CO_2 is created by volcanic eruptions, which accounts for 0.03% of natural emissions. Volcanic eruptions release magma, ash, dust and gases from deep below the Earth's surface. One of the gases released is CO_2. Annually this process creates about 0.15 to 0.26 billion tons of CO_2 emissions (Gerlach and Terry, 2011).

2.3.2 Anthropogenic induced increase in atmospheric carbon(iv) oxide concentration

Tans (2009) explained that multiple lines of observational evidences indicated that during the past few decades, the atmospheric CO_2 concentration has significantly increased and most of the increase came from fossil fuel combustion. Solomon *et al* (2007) in the contribution of Working Group I to the Fourth Assessment Report of the IPCC concluded that the concentration of atmospheric CO_2 has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005. It was revealed that atmospheric CO_2 concentration increased by only 20 ppm over the 8000 years prior to industrialization and that multi-decadal to centennial-scale variations during these periods were less than 10 ppm and likely due mostly to natural processes.

However, since 1750 (the beginning of industrial era), the concentration of CO_2 has risen by nearly 100 ppm. This observation was continued in the fifth assessment report where Hartmann *et al*., (2013) illustrated that CO_2 has increased by another 11.7 ppm to 390.5 ppm between 2005 and 2011. It was revealed that the average annual increase in globally averaged CO_2 (from 1 January in one year to 1 January in the following year) since 1980 has been 1.7 ppm yr^{-1}.

According to IPCC (2007), evidences proved that the post-industrial rise in atmospheric CO_2 concentration does not stem from natural mechanisms and in fact the primary sources of this increase is as a result of human activities from fossil fuel use and the effects of land use change on plant and soil carbon. It was revealed that since 1750, it was estimated that about two-third of anthropogenic CO_2 emissions have come from fossil fuel burning and about one-third from land use change. It was also revealed that about 45% of this CO_2 has remained in the atmosphere, while about 30% has been taken up by the oceans and the remainder has been taken up by the terrestrial biosphere. In line with this, Barker *et al* (2007) stated that it is absolutely certain that since pre-industrial times, human activities such as combustion of fossil fuel and land use have led to a marked increase in atmospheric CO_2 concentrations. It was revealed in their study that between 1970 and 2004, global emission of the Kyoto gases i.e. the most important climate relevant GHGs CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, have increased by 70% from 28.7 to 49 $GtCO_2$-eq. Barker *et al* (2007) also mentioned that the emissions of these gases have increased at different rates with CO_2 emissions having grown between 1970 and 2004 by about 80% and 28% between 1990 and 2004 and represents about 77% of total anthropogenic GHG emissions in the year 2004. The largest growth in global CO_2 emissions between 1970 and 2004 came from the energy supply sector with the transport sector contributing most to CO_2 emissions, then followed by the industrial sector (Oliver *et al*., 2014).

2.3.3 Industrial CO_2 emissions

In 2010, the global industry sector accounted for around 28 % of final energy use (IEA, 2013). Industrial CO_2 emissions were 13.14 $GtCO_2$. These emissions were comprised of 5.27 $GtCO_2$ direct energy-related emissions, 5.25 $GtCO_2$ indirect emissions from electricity and heat production, 2.59 $GtCO_2$ from industrial process CO_2 emissions and 0.03 $GtCO_2$ from waste/wastewater. Process CO_2 emissions are comprised of process-related emissions of 1.352 $GtCO_2$ from cement production, 0.477 $GtCO_2$ from production of chemicals, 0.242 $GtCO_2$ from lime production, 0.134 $GtCO_2$ from coke ovens, 0.074 $GtCO_2$ from non-ferrous metals production, 0.072 $GtCO_2$ from iron and steel production, 0.061 $GtCO_2$ from ferroalloy production, 0.060 $GtCO_2$ from limestone and dolomite use, 0.049 $GtCO_2$ from solvent and other product use, 0.042 $GtCO_2$ from production of other minerals and 0.024 $GtCO_2$ from non-energy use of lubricants/waxes (Joint Research Centre JRC/ Netherlands Environmental Assessment Agency,(2013)).

Manufacturing is a subset of industry that includes production of all products (e.g., steel, cement, machinery, textiles) except for energy products, and does not include energy used for construction (Fischedick *et al*., 2014). Manufacturing is responsible for about 98 % of total direct CO_2 emissions from the industrial sector (IEA, 2012). Most manufacturing CO_2 emissions arise due to chemical reactions and fossil fuel combustion largely used to provide the intense heat that is often required to bring about the physical and chemical transformations that convert raw materials into industrial products. These industries, which include production of chemicals and petrochemicals, iron and steel, cement, pulp and paper, and aluminums, usually account for most of the sector's energy consumption in many countries. In India, the share of energy use by energy-intensive manufacturing industries in total manufacturing energy consumption is 62 % (Indian Network for Climate Change Assessment INCCA, 2010), while it is about 80 % in China (National Bureau of Statistics NBS, 2012). The share of non-energy use of fossil fuels (e.g., the use of fossil fuels as a chemical industry feedstock, of refinery and coke oven products, and of solid carbon for the production of metals and inorganic chemicals) in total manufacturing final energy use has grown from 20 % in 2000 to 24 % in 2009 (IEA, 2012).

Overall reductions in industrial energy use/manufacturing value added were found to be greatest in developing economies during 1995–2008. Low-income developing economies had the highest industrial energy intensity values while developed economies had the lowest. Reductions in intensity were realized through technological changes (e.g., changes in product mix, adoption of energy-efficient technologies, etc.) and structural change in the share of energy intensive industries in the economy. During 1995–2008, developing economies had greater reductions in energy intensity while developed economies had greater reductions through structural change (United Nations Industrial Development Organization UNIDO, 2011).

2.3.4 Mitigation technology, practices and behavioural changes options for CO_2 emission management.

Fischedick *et al*., (2014) reported that there are quite a number of technological options and practices as well as behavioral changes that are significant potential mitigation opportunities for CO_2 emission in the industrial sector and this includes: Energy efficiency: Energy is used in industry to drive chemical reactions, to create heat, and to perform mechanical work (Dasgupta *et al*., 2012). Energy efficiency has been an important strategy for industry for various reasons for a long time. There are many options for energy efficiency improvement and there is significant potential to reduce the gap between actual energy use and the best practice in many industries and in most countries. For all, but particularly for less energy intensive industries, there are many energy efficiency options both for process and system-wide technologies and measures. Several detailed analyses related to particular sectors estimate the technical potential of energy efficiency measures in industry to be approximately up to 25% (Schäfer, 2005; Allwood *et al*., 2010; UNIDO, 2011; Saygin *et al.*, 2011). Through innovation, additional reductions of approximately up to 20% in energy intensity may potentially be realized before approaching technological limits in some energy intensive industries (Allwood *et al*., 2010).

In industry, energy efficiency opportunities are found within sector specific processes as well as in systems such as steam systems, process heating systems (furnaces and boilers), and electric motor systems (e.g., pumps, fans, air compressor, refrigerators, material handling). As a class of technology, electronic control systems help to optimize performance of motors, compressors, steam combustion, heating, etc. and improve plant efficiency cost-effectively with both energy savings and emissions benefits, especially for Small and Medium Enterprises (SMEs) (Masanet, 2010). Opportunities to improve heat management include better heat exchange between hot and cold gases and fluids, improved insulation, capture and use of heat in hot products, and use of exhaust heat for electricity generation or as an input to lower temperature processes (United State Department of Energy US DoE, 2004, 2008). However, the value of these options is in many cases limited by the low temperature of waste heat industrial heat exchangers generally require a temperature difference of ~200 °C and the difficulty of exchanging heat out of solid materials. Recycling can also help to reduce energy demand, as it can be a strategy to create material with less energy. Recycling is already widely applied for bulk metals (steel, aluminium, and copper in particular), paper and glass. This has lead to an energy saving when producing new material from old and has been used to avoid the need for further energy intensive chemical reactions.

Emissions efficiency: In 2008, 42 % of industrial energy supply was from coal and oil, 20% from gas, and the remainder from electricity and direct use of renewable energy sources. These shares are forecast to change to 30 % and 24 % respectively by 2035 resulting in lower emissions per unit of energy (IEA, 2011a). Switching to natural gas favors more efficient use of energy in industrial combined heat and power (CHP) installations (IEA, 2008, 2009a). CHP offers useful load balancing opportunities if coupled with low-grade heat storage (IEA, 2011b). The use of wastes and biomass in the energy industry is currently limited, but forecasted to grow if electricity generation is decarbonized (IEA, 2009b). Greater electrification, for example appropriate use of heat pumps instead of boilers could also reduce emissions (IEA, 2009b; HPTCJ, 2010). Solar thermal energy for drying, washing, and evaporation may also be developed further, although to date this has not been implemented widely (Sims *et al*., 2011).

Also, the International Energy Agency (IEA, 2009c) forecasted that a large part of emission reduction in industry will occur by CO_2 capture and storage (CCS) (up to 30 % in 2050).

In gas processing and parts of the chemical industry (ammonia production without downstream use of CO_2), there might be early opportunities for application of CCS as the CO_2 in vented gas is already highly concentrated (up to 85%), compared to cement or steel (up to 30%) (Kuramochi *et al*., 2012). Industrial utilization of CO_2 was assessed in the IPCC Special Report on Carbon Dioxide Capture and Storage (SRCCS) (Mazzotti *et al*., 2005) and it was found that potential industrial use of CO_2 was rather small and the storage time of CO_2 in industrial products often short. Therefore industrial uses of CO_2 are unlikely to contribute to a great extent to climate change mitigation. However, currently CO_2 use is subject of various industrial research and development, projects (Fischedick *et al*., 2014).

Material efficiency in production: Material efficiency i.e. delivering services with less new material is a significant opportunity for industrial emissions abatement, which has had relatively little attention to date (Allwood *et al*., 2012). Two key strategies would significantly improve material efficiency in manufacturing existing products:

i. Reducing yield losses in materials production, manufacturing, and construction. Approximately one-tenth of all paper, a quarter of all steel, and a half of all aluminium produced each year is scrapped (mainly in downstream manufacturing) and internally recycled. This could be reduced by process innovations and new approaches to design (Milford *et al*., 2011).

ii. Re-using old material. A detailed study (Allwood *et al*., 2012) on re-use of structural steel in construction concluded that there are no insurmountable technical barriers to re-use, that there is a profit opportunity, and that the potential supply is growing.

Material efficiency in product design: Many products could be one-third lighter without loss of performance in use (Carruth *et al.*, 2011) if design and production were optimized. At present, the high costs of labour relative to materials and other barriers inhibit this opportunity, except in industries such as aerospace where the cost of design and manufacture for lightness is paid back through reduced fuel use. Substitution of one material by another is often technically possible (Ashby, 2009), but options for material substitution as an abatement strategy are limited. However material efficiency in product design could provide a significant reduction in emission if it is given adequate consideration.

Using products more intensively: Products, such as food, that are intended to be consumed in use are in many cases used inefficiently, and estimates show that up to one-third of all food in developed countries is wasted (Gustavsonn *et al.*, 2011). This indicates the opportunity for behavioural changes to reduce significantly the demand for industrial production of what currently becomes waste without any service provision. In contrast to these consumable products, most durable goods are owned in order to deliver a product service rather than for their own sake, so potentially the same level of service could be delivered with fewer products. Using products for longer could reduce demand for replacement goods, and hence reduce industrial emissions (Allwood *et al*., 2012). New business models could foster dematerialization and more intense use of products.

Reducing overall demand for product services: Industrial emissions would be reduced if overall demand for product services were reduced (Kainuma *et al*., 2013); if the population chose to travel less (e.g., through more domestic tourism or telecommuting), heat or cool buildings only to the degree required, or reduce unnecessary consumption or products. Clear evidence that beyond some threshold of development, populations do not become happier (as reflected in a wide range of socio-economic measures) with increasing wealth, suggests that reduced overall consumption might not be harmful in developed economies (Layard, 2011; Roy and Pal, 2009).

These GHG mitigation options and there area of possible application over the product supply chain are illustrated in Figure 2.2. Options for GHG mitigation in the industry sector are indicated by the circled numbers:

(1) Energy efficiency (e.g., through furnace insulation, process coupling, or increased material recycling),

(2) Emissions efficiency (e.g., from switching to non-fossil fuel electricity supply, or applying carbon capture and storage technology),

(3a) Material efficiency in manufacturing (e.g., through reducing yield losses in blanking and stamping sheet metal or re-using old structural steel without melting),

(3b) Material efficiency in product design (e.g., through extended product life, light weight design, or de-materialization),

(4) Product-Service efficiency (e.g., through car sharing, or higher building occupancy) and

(5) Service demand reduction (e.g., switching from private to public transport).

2.3.5 Nigeria greenhouse gas inventory

Since the submission of the First National Communication in 2003, Nigeria has updated her national GHG inventory from the year 1988 up to the year 2000. The procedure adopted in the development of the inventory involved the use of the default methodology of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories where all processes leading to the emission of a GHG or its precursor gas were identified.

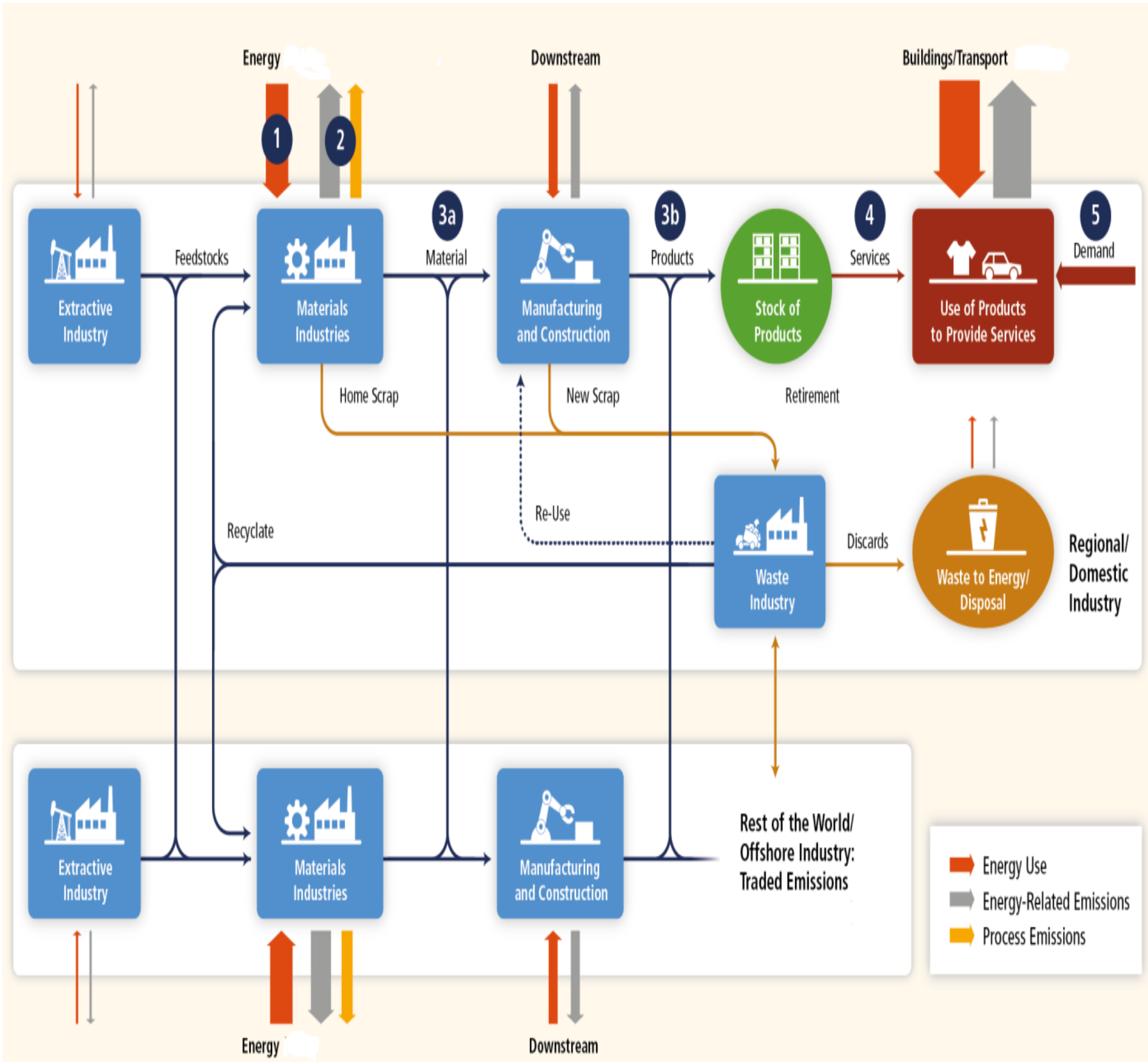

Figure 2.2 A schematic illustration of industrial activity over the supply chain and areas where GHG reduction opportunities lie.

Source: Fischedick *et al*., 2014

Then the activity data (A) that quantify the GHG emission which were obtained mostly from national data sources like published data by the Nigerian National Petroleum Corporation (NNPC), National Bureau of Statistics (NBS) and Central Bank of Nigeria (CBN) were multiplied by emission factor (F) or emissions per unit of activity which were extracted from IPCC (1996) default emission factor database (Federal Ministry of Environment, 2014).

The inventory which uses sectoral (bottom-up) approach to estimate the GHG emissions from energy, industrial processes, agriculture, land use, land-use change and forestry, waste and solvent and other product use sectors showed that the CO_2 equivalent emissions for the period 1988 – 2000 indicated gross CO_2 emissions per annum ranging from 200 teragram (Tg-CO_2-e) in 1988 to 318 Tg-CO_2-e in the year 2000. Out of these, CO_2 contribution was highest and in the range 147 – 214 Tg-CO_2-e while N_2O contribution is least, and in the range 6.1–7.1 Tg-CO_2-e (Federal Ministry of Environment, 2014). The relative contribution of the three GHGs to gross CO_2 equivalent emissions show that CO_2 contributed about 71% of the gross CO_2- e during the period with a mean annual growth rate of 3.3%, followed by CH4 (26%) and N_2O (less than 5%) (Federal Ministry of Environment, 2014).With these results, the federal ministry of environment concluded that it therefore becomes imperative to note that that at a minimum, Nigeria may double its current annual emissions in the time frame of 30 years if the population growth rates as well as the consumption patterns continue to increase (Federal Ministry of Environment, 2014).

Furthermore, the inventory shows that in the year 2000 (the base year used for the last inventory calculation), Nigeria contributed about 318,075 TgCO_2-e to the atmosphere and energy-related activities have the dominant share of this proportion followed by agriculture, with very minimal contributions from waste and industrial processes (non energy GHG emission). The total emissions from the energy sector were 224,082.94 $TgCO_2$-e, representing 70.4% of the country's total GHG emission in the year 2000. CO_2 was the largest contributor (165,821.36 $TgCO_2$-e) at a percentage of 74% of the total energy sector emissions. Within the energy sector, the manufacturing subsector represents the third largest contributor to energy sector GHG emission after gas flaring and transportation (Federal Ministry of Environment, 2014).

2.3.6 CO_2 emission in Nigeria

In Nigeria, the contribution of locally emitted GHG to global warming has been assessed by different authors. In 2015, Edeoja and Edeoja evaluated the management of carbon emissions in the Nigerian construction industry by measuring the amount of CO_2 being emitted from constructional activities within some selected organizations. The study was pursued via three case study analysis within the industry, scope 1 and scope 2 emissions according to GHG protocol classification were the considered emission sources. It was found that though there was a significant emission from the Nigerian construction industry, the provision for emissions monitoring and management was lacking, the general awareness regarding carbon emissions and environmental issues across the various organizations evaluated was poor and the construction organizations had no singular person directly in charge of carbon or environmental issues.

Anomohanra (2011) investigated the amount of CO_2 emission released from the consumption of petroleum product in Nigeria between 1999 and 2009. Tier 1 method of GHG determination using the reference approach was adopted, this method involves the estimation of CO_2 emission from the supply of petroleum product to the economy rather than from the actual emission at the combustion plant. The result indicated that Nigeria was responsible for 0.26% of global CO_2 emission within the time frame. The study also reported that the consumption of premium motor spirit, automated gas oil and house hold kerosene constituted 85% of the total emission for the previous 20 years and that there was a yearly increase in CO_2 emission by 4.7% as against the global 1.9% within the same time frame.

A similar study was also conducted by Anomohanra (2012) on greenhouse gas emission resulting from gas flaring activities in Nigeria between the period of 1999 and 2009. The study made use of records of natural gas produced and natural gas flared in Nigeria within the time frame and the reference approach method of greenhouse gas determination was also adopted. The result showed that 47% of the total gas produced within the period was flared. The result also indicated that the total quantity of CO_2 emitted within the time frame was 23.1% when compared with that of the global value and it represents one of the largest emissions from a single source.

Nwaichi and Uzazobona (2011) delve into exploring the level and distribution of CO_2 and other associated potential contaminants in the Niger Delta. In the study, some flare sites were investigated to examine their possible environmental characteristics. Two flow stations of Shell Petroleum Corporation were monitored for a period of three months. It was ascertained that the concentration of CO_2 and other contaminants were significant and that the flaring activities have substantially impacted on the environment through emission and as a result, require mitigation measures to avoid the inherent biomagnification with time.

Iduh *et al.*, (2016) highlighted the potential reduction of CO_2 emissions from gas flaring in Nigeria's Oil and Gas Industry through Alternative Productive Use. The study investigated the potentials of converting flared gas from the Nigerian oil and gas industry to compressed natural gas (CNG) which could be an alternative fuel for the 220 Lagos Bus Rapid Transit (BRT-Lite) while reducing CO_2 emissions. In addition, the study provided an overview of gas flaring in the oil and gas industry and energy utilization in some selected sectors in the country. The study concluded that the use of CNG as an alternative fuel for Lagos BRT-Lite will significantly reduce CO_2 emissions in Nigeria's oil and gas industry and other utilization options for flared gas from this industry includes: Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), and power generation.

Okhimamhe and Okelola (2013) in a study of the assessment of the levels of atmospheric carbon dioxide emission at road junctions in three major cities in the southeast of Niger State in Nigeria, namely Minna, Bida and Suleja identify measures that improve traffic operations while reducing the emission levels that could have implications on global warming and hence climate change. The results established that the emission levels in these three cities was approximately eight times more than the internationally accepted safe limits of 350ppm for atmospheric CO_2, but less than the Occupational Safety and Health Administration permissible exposure limits of 5,000ppm which has adverse health effects, and may contribute to climate change, in the long term, if unmitigated.

Ekundayo (2015) focused on the relationship between carbon emission and economic growth in Nigeria from 1970 to 2013. The research employed carbon emission, real gross domestic product, capital investment, and trade openness in carrying out the analysis. Error correction model was used in the study, and the result clearly showed that in the first period, economic growth positively impacts carbon emission, while it negatively impacts carbon emission in the lagged period. It also revealed that trade openness and capital investment, positively impact carbon emission in Nigeria. It was recommended that since a reduction in GDP (in an attempt to curb carbon emission) can harm the country's economic progress, it is expedient to look for ways to promote green growth in the country. Therefore, policy makers must put in place measures that guide against the dumping of environmentally unfriendly products into the country, and in order to ensure that capital investment do not contribute to carbon emission in the country, Nigeria can use its infrastructure deficit to leapfrog to greener investments by using environmentally sound technologies and innovations that are currently available.

Okorie and Sosoo (2017) also investigated the dynamics of CO_2 emission on Nigerian capacity utilization. The study discovered that at present, emission of CO_2 is statistically significant and positively related to the Average Manufacturing Capacity Utilization (AMCU) in the short and long run, denoting that the emission of CO_2 is in-line with green economics; which however will not jeopardize future production and consumption. On the other hand, Manufacturing Value Added (MVA) is inversely related with Average Manufacturing Capacity Utilization (AMCU), in the short and long-run. it was then suggested that there should be utilization of available capacities in adding value to goods and services and a more effective and tightened Carbon Emission Tax System (CETS) like Cap-and-Trade, Carbon Tax, Pigouvian Tax, etc. which will keep in check, the quantity of Emitted CO_2 in Nigeria and consequently, not affect the birds of the air and earth (Livestock), aquatic animals, and human beings. Hence creating a future better Nigeria with respect to production and Consumption.

Samson *et al*., (2013) probed into CO_2 electricity generation prospect in Nigeria. The study exploited the ability of CO_2 exhaust gas from the power plant with the aid of the carbon dioxide data obtained from IEA through the ministry of Environment in Nigeria and the knowledge of bottoming power generation. Also, qualitative amount of power was estimated from the nation industrial CO_2 potential generation. The result shows that an optimum amount of 564.7MW of electricity per year could be estimated from this power source; this is equivalent to 10.8% of projected power required for year 2030.

Igwenagu (2011) examined the position of Nigeria in relation to CO_2 emission readiness for emission trading as proposed in the Kyoto protocol as a measure of reducing global warming. It was discovered that Nigeria emits only 0.4% of the total world CO_2 emission which indicate that Nigeria will be possible seller of emission as contained in the protocol.

2.3.7 Greenhouse gas background science and regulation

2.3.7.1 *Science*

The Intergovernmental Panel on Climate Change (IPCC) is a scientific body responsible for reviewing and assessing global scientific information relevant to climate change. The IPCC was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) and endorsed by the United Nations General Assembly (Robyn *et al*., 2013). The IPCC reviews and assesses the most recent scientific, technical and socioeconomic information provided by member countries relevant to the understanding of climate change. Fundamental research is conducted around the world by environmental agencies, national and university laboratories; this research is fed into and consolidated by the IPCC into periodic reports on the state of climate change and climate science.

The IPCC has created a globally accepted methodology for country-level estimation of GHGs from each major sector of the economy. This methodology is based on research conducted around the world, and has resulted in generalized equations with lookup factors for specific countries and other factors. Each participating country provides an annual report of their GHG emissions to the IPCC; typically this report is provided by the country's national environmental agency. Among other critical scientific information, the IPCC updates the global GHG reporting standards for all nations reporting under the UNFCCC, as well as the global warming potential

(GWP) of each GHG which is calculated based on its heat-trapping capability relative to CO_2. The IPCC's role is critical in contributing toward a globally harmonized protocol for high level GHG emissions accounting that can be utilized throughout the world. In fact, the IPCC GHG methodology is perhaps the closest to a globally harmonized approach. Nonetheless, while the IPCC methodology is considered to be adequate for high level government reporting it is only a starting point for assessing actual GHG emissions from specific sectors and facilities (Robyn *et al*., 2013).

2.3.7.2 *Regulation*

Around the world many countries and regions have put in place or are discussing legislation which requires GHG reporting. The foundation for nearly all of the methodologies provided in the resulting regulations find their origin in the work of the UNFCCC and IPCC (Robyn *et al*., 2013). The UNFCCC is an international treaty adopted in 1992 and ratified in 1994 that recognized the problem and encouraged industrialized countries to curtail emissions to levels that would prevent interference with the climate system (US EPA. 2009). As of September 2011, 194 countries plus the European Union (EU) have ratified the Convention.

The UNFCCC strengthened the engagement of industrialized nations interested in meeting their GHG targets to a higher level of commitment with the ratification of the Kyoto Protocol in 2005 (Robyn *et al*., 2013). The Kyoto Protocol requires all signatory countries to monitor, at a national scale, their emissions of six key GHGs: (i) CO_2, (ii) CH_4, (iii) N_2O, (iv) HFCs, (v) PFCs, and (vi) SF_6. These are emissions reported annually by each participating country to the IPCC using the IPCC GHG methodology (US EPA. 2009). As the UNFCCC work has progressed, all of the ratifying countries have conducted work of their own to measure and to curtail GHG emissions and comply with the Kyoto Protocol. These efforts typically originate from the country's environmental agency, and have generally been specific to the highest GHG generating sectors of that country's economy. In some cases this work has been delegated to the agencies responsible for regulating the individual sectors (Robyn *et al*., 2013).

2.3.7.3 *Parties to the Kyoto protocol*

The parties/countries under the protocol belong into three main groups according to differing commitments. These are examined under Annex I, Annex II and Non Annex I.

ANNEX I Parties include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (The EIT) Parties e.g. Bulgaria, Croatia, Hungary, Estonia, e.t.c including the Russian Federation, the Baltic States, and several Central and Eastern European States. A requirement that affects only Annex I Parties is that they must adopt climate change policies and measures with the aim of reducing their greenhouse gas emissions to 1990 levels by the year 2000. This provision obliges them to set an example of firm resolve to deal with climate change. The Convention grants EIT Parties a certain degree of flexibility in implementing commitments, on account of recent economic and political upheavals in those countries. Several EIT Parties have exercised this flexibility to select a base year other than 1990 for their specific commitment, to take account of intervening economic changes that led to big cuts in emissions (UNFCCC, 2003).

ANNEX II Parties consist of the OECD members of Annex I (Australia, Germany, Italy, Belgium, France, United Kingdom, Spain etc.) but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to take all practicable steps to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries. Funding provided by Annex II Parties is channeled mostly through the Convention's financial mechanism (UNFCCC, 2003).

NON-ANNEX I Parties as they are termed for ease of reference are mostly developing countries (Nigeria, Algeria, Mexico, Argentina, Barbados, Bolivia, Brazil, Cameroon, Chile, Haiti, Morocco etc.). Certain groups of developing countries are recognized by the Convention as being especially vulnerable to the adverse impacts of climate change, including countries with low-lying coastal areas and those prone to desertification and drought. Others (such as countries that rely heavily on income from fossil fuel production and commerce) feel more vulnerable to the potential economic impacts of climate change response measures. The Convention emphasizes activities that promise to answer the special needs and concerns of these vulnerable countries, such as investment, insurance and technology-transfer. The 48 countries classified as least developed countries (Burundi, Central African Republic, Chad, Djibouti, Eritrea, Equatorial Guinea, Angola, Malawi, Gambia, Somalia Uganda e.t.c.) by the United Nations are given special consideration under the Convention on account of their limited capacity to respond to climate change and adapt to its adverse effects. Parties are urged to take full account of the special situation of least developed countries when considering funding and technology-transfer activities (UNFCCC, 2003).

All Parties to the Convention – those countries that have ratified, accepted, approved, or acceded to it are subject to general commitments to respond to climate change. They agree to compile an inventory of their greenhouse gas emissions, and submit reports known as national communications on actions they are taking to implement the Convention. To focus such actions, UNEP, (2012) observed that they must prepare national programmes containing:

i. Climate change mitigation measures
ii. Provisions for developing and transferring environmentally friendly technologies
iii. Provisions for sustainably managing carbon sinks (a general term for forests and other ecosystems that can remove more greenhouse gases from the atmosphere than they emit)
iv. Preparations to adapt to climate change
v. Plans to engage in climate research, observation of the global climate system and information exchange
vi. Plans to promote education, training and public awareness relating to climate change.

2.3.7.4 *Regulatory reporting requirements in Nigeria*

Nigeria is a non-annex (developing nation) member party of the UNFCCC (Clean Development Mechanism CDM, 2012). As such, it is currently not required to reduce its GHG emissions, and at the same time it is eligible to receive assistance from Annex II countries to help reduce its emissions and adapt to climate change (CDM, 2012). Outside of the UNFCCC process, little additional regulatory activities have taken place to curb GHGs or reduce energy consumption. Recognizing that the nation is both a significant contributor to anthropogenic carbon emissions, and is at significant risk for the impacts of altered climate patterns, Nigeria has taken a few first steps towards assuming its fair share of responsibility in climate change mitigation and also planning adaptation strategies. The country has done its first and second national GHG inventory. It has also stated a goal for leveling and subsequently reducing its GHG emissions (dubbed the intended nationally determined contribution) in a way that still allows for sustainable development. The culmination of all the country's efforts so far is a strategic policy titled the Nigeria Climate Change Policy Response and Strategy, adopted in 2012 by the Federal Executive Council (Federal Ministry of Environment, 2015). The policy is still far from setting emission restrictions or assigning reduction targets by activities, but it starts by defining some set of objectives in order to foster low-carbon, high growth economic development and build a climate resilient society. These objectives are to be implemented within the period of 2015- 2030 and will first focus on the significant emitting industries, namely major energy supply (electricity and liquid fuels) and use (industry and transport) sectors. The idea of the policy is to provide the greatest flexibility and lowest cost alternative for reaching the emission reduction targets for each sector of the economy (Federal Ministry of Environment, 2015). According to the document, under a business-as-usual growth scenario, consistent with strong economic growth of 5% per year, Nigeria's emissions are expected to grow to around 900 million tons per year in 2030, which translates to around 3.4 tons per person. The key mitigation measures defined in the policy could potentially reduce emissions by around (45%) compared to business as usual (Federal Ministry of Environment, 2015).

2.3.8 GHG emission reporting: scopes

The World Resource Institute GHG Protocol allows for the attribution of GHG emissions according to different levels of ownership (WRI, 2006). These procedures introduce the concept of scope of emissions, which distinguishes direct facility ownership emissions from emissions resulting from broader company activities. Scope 1 emissions are owned or controlled by the company (producer) and include, for example, onsite emissions from boilers, furnaces, and vehicles. Scope 2 (consumer) encompasses emissions during the generation of purchased electricity and heat. Scope 3 (consumer) includes offsite emissions during extraction and production of purchased materials, transportation of workers and supplies, and end product use (WRI, 2006). Scope 3 emissions do not have to incorporate a full life cycle assessment, but need to practically assess the major indirect emissions attributable to the company's activities (Kennedy *et al*., 2011).

2.3.9 Emissions trading or cap and trade

Emissions trading or cap and trade is a government-mandated, market-based approach to controlling pollution by providing economic incentives for achieving reductions in the emissions of pollutants (Stavins and Robert, 2001). In contrast to command-and-control environmental regulations such as best available technology (BAT) standards and government subsidies, cap and trade schemes are a type of flexible environmental regulation that allows organizations to decide how best to meet policy targets (Teeter, Preston, Sandberg, Jorgen, *2*016). Various countries, states and groups of companies have adopted such trading systems, notably for mitigating climate change.

A central authority (usually a governmental body) allocates or sells a limited number of permits to discharge specific quantities of a specific pollutant per time period. Polluters are required to hold permits in amount equal to their emissions. Polluters that want to increase their emissions must buy permits from others willing to sell them (Stavins and Robert, 2001). In theory, polluters who can reduce emissions most cheaply will do so, achieving the emission reduction at the lowest cost to society. Cap and trade is meant to provide the private sector with the flexibility required to reduce emissions while stimulating technological innovation and economic growth. There are active trading programs in several air pollutants. For greenhouse gases, which may cause dangerous climate change, permit units are often called *carbon credits.* The largest greenhouse gases trading program is the European Union Emission Trading Scheme, which trades primarily in *European Union Allowances* (*EUAs*), the Californian scheme trades in California Carbon Allowances, the New Zealand scheme in New Zealand Units and the Australian scheme in Australian Units (Teeter *et al*., 2016). Figure 2.3 shows a diagrammatic representation of the working mechanism of the emission trading programme.

2.3.10 Carbon emission measurement

Measurement of CO_2 emission can be approached either by the use of kit or gadget that detects GHGs on the basis of flue gas flow measurements, this is known as the Continuous Emission Monitoring (CEM) method or by way of appropriate documented emission factors and activity data. However, the most common and internationally recognized approach is through the application of documented emission factors because it is a more flexible method to use and it is less costly as compared to the CEM method (Greenhouse Gas Protocol, 2004). Emission factors are calculated ratios corresponding to the amount of greenhouse gas emitted as a result of a given unit of activity (E3 solutions, 2014). For example, the burning of one cubic meter of natural gas will typically emit1879grams of CO_2, 0.037g of CH_4 and 0.033g of N_2O which are the emission factors of the three GHG for natural gas combustion (E3 solutions, 2014).Typically, when an emission factor is listed it will be listed with a unit of quantity of the GHG over a functional unit of activity e.g. grams of CO_2 emitted per liter of diesel combusted. Emission factors are often documented in academic and scientific research papers and are also provided by government institutions like GHG protocol and the IPCC (E3 solutions, 2014). These emission factors are then multiplied by the appropriate activity data e.g. the volume of natural gas combusted in a boiler for a given duration to give an estimate of the GHGs emitted for that period. The emission factor/activity data based method is usually being applied based on tiers (tier 1 to 3) depending

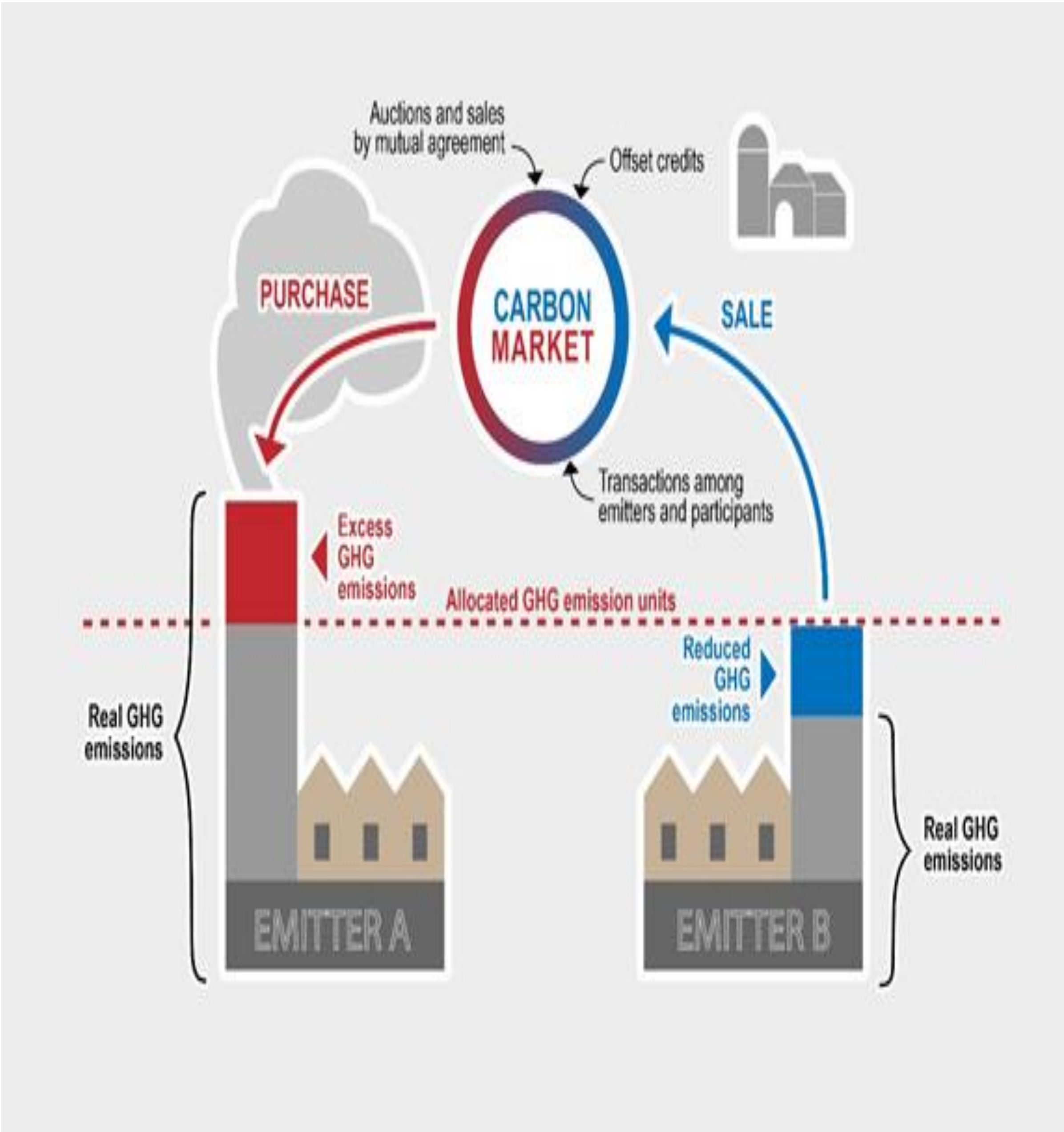

Figure 2.3: A diagrammatic representation of the working mechanism of the emission trading programme (Cap and Trade).

Source: Government de Quebec, 2016

on the comprehensiveness of the available data and resources (time, expertise and country-specific data). Applying a tier 1 emission estimate requires data on the amount of fuel combusted in the source category and a default emission factor. The equation is represented as thus.

$$\text{Emission}_{\,GHG,\,fuel} = \text{Fuel consumption}_{\,fuel} \times \text{Emission factor}_{\,GHG,\,fuel} \qquad (2.2)$$

Where Emissions $_{GHG,\ fuel}$ = emissions of a given GHG by type of fuel and Fuel Consumption $_{fuel}$ = amount of fuel combusted. Emission Factor $_{GHG,\ fuel}$ = default emission factor of a given GHG by type of fuel (IPCC, 2006).

Under Tier 2, the Tier 1 default emission factors are replaced by country-specific emission factors. Country-specific emission factors can be developed by taking into account country-specific data, for example carbon contents of the fuels used, carbon oxidation factors, fuel quality and (for non-CO_2 gases in particular) the state of technological development (IPCC, 2006). Application of a Tier 3 emission estimation approach requires data on the following:

i. The amount of fuel combusted in the source category for each relevant technology (fuel type used, combustion technology, operating conditions, control technology, and maintenance and age of the equipment.
ii. The specific emission factor for each technology (fuel type used, combustion technology, operating conditions, control technology, oxidation factor, and maintenance and age of the equipment) (IPCC, 2006).

$$\text{Emission}_{\,GHG,\,fuel,\,technology} = \text{Fuel consumption}_{\,fuel,\,technology} \times \text{Emission factor}\,CO_{2,\,fuel,\,technology}$$

where Emissions $_{GHG,\ fuel,\ technology}$ = Emissions of a given GHG by type of fuel and technology. Fuel Consumption $_{fuel,\ technology}$ = Amount of fuel combusted per type of technology. Emission

Factor $_{GHG\ fuel,\ technology}$ = Emission factor of a given GHG by fuel and technology type (IPCC, 2006).

Using a tier 3 approach to estimate an emission of CO_2 is often unnecessary because emissions of CO_2 do not depend on the combustion technology. However, Plant-specific data on CO_2 emissions are increasingly available and they are of increasing interest because of the possibilities for emissions trading (IPCC, 2006).

2.3.11 Comparing methodologies

Both direct measurement and calculation-based approaches are acceptable ways to estimate CO_2 emissions from stationary combustion (Robyn *et al*., 2013). Direct measurement methods usually take the form of a continuous emissions monitoring (CEM) system that records the total flow rate and CO_2 concentration of exhaust gases in a stack or duct, although they can also take the form of discontinuous measurements made for verification or calibration purposes (Robyn *et al*., 2013). Calculation based methods usually involve the monitoring of fuel consumption rates, fuel composition, and adjustments for the fraction of carbon that remains unoxidized. In principle, one would expect the direct measurement of greenhouse gas emissions to be the preferred method for stationary combustion sources. However, in practice it can be both expensive and difficult to accurately measure exhaust gas concentrations and flow rates at combustion facilities (IPCC, 2006).

To ensure accurate results, CEM or other direct measurement systems require rigorous calibration and verification procedures. In contrast, calculation methods for CO_2 benefit from the close relationship between the carbon content of fuels and emissions and can generally be implemented at lower costs. Therefore, CEM systems are not necessarily more accurate than calculation based methods for estimating CO_2 emissions, although in most cases they will be more expensive to install and operate (IPCC, 2006). The relative accuracy of an emissions estimation approach strongly depends on the quality of the data collected and the rigor of quality control measures (Robyn *et al*., 2013). Given similar levels of data quality and quality control both direct measurement and calculation based approaches are capable of producing accurate CO_2 emission estimates. However, the extra cost of a direct measurement approaches such as CEM systems typically cannot be justified for the purpose of estimating CO_2 emissions alone. If CEM systems are installed for the purpose of monitoring emissions of other pollutants, however, they can provide an excellent source of real time data that can be used to verify or be verified by fuel based emission estimates (IPCC, 2006).

CHAPTER THREE: STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter presents the study area and the methodology adopted in order to achieve the set objectives of this research. The study area is discussed in line of its location and size, geology and relief as well as the socioeconomic activities it provides. The methodology which focused on how the emitted CO_2 from the assessed industries was measured and how its management practices were observed help to bring out the validity and reliability of the data collected.

3.2 The Study Area

3.2.1 Location and size

Agbara Estate is a model integrated town development on 454.1 hectares of land and it is being managed by Agbara Estate (AE) Property Services Limited, a subsidiary of Lawson's Corporation Nigeria Limited. It is situated approximately 31 kilometers west of Lagos on the Lagos-Badagry expressway on high ground above the Owo River and derives its name from the neighboring Agbara village. The estate lies at the boundary of Ogun State, Nigeria and located between latitude 6°27' and 6°45' North and longitude 3°23' and 3°49' East (Agbara Estate Limited AEL, 2008). The study area is presented in Fig 3.1.

3.2.2 Geology and relief

Agbara Estate is on a laterite outcrop in an area of lowland behind the swamp forest of the Ologe Lagoon. It is fairly flat and approximately 50 feet above the sea level, gently sloping into Owo River and the swamp areas to the south and east while gently undulating to the north and west. A few valleys dissect the site which is in an area of recent geological deposits with sandbanks and creeks behind the coast and a laterite outcrop to the north of the Badagry laterite 200mm to 250mm in depth with a low humus content and low pH level (AEL, 2008).

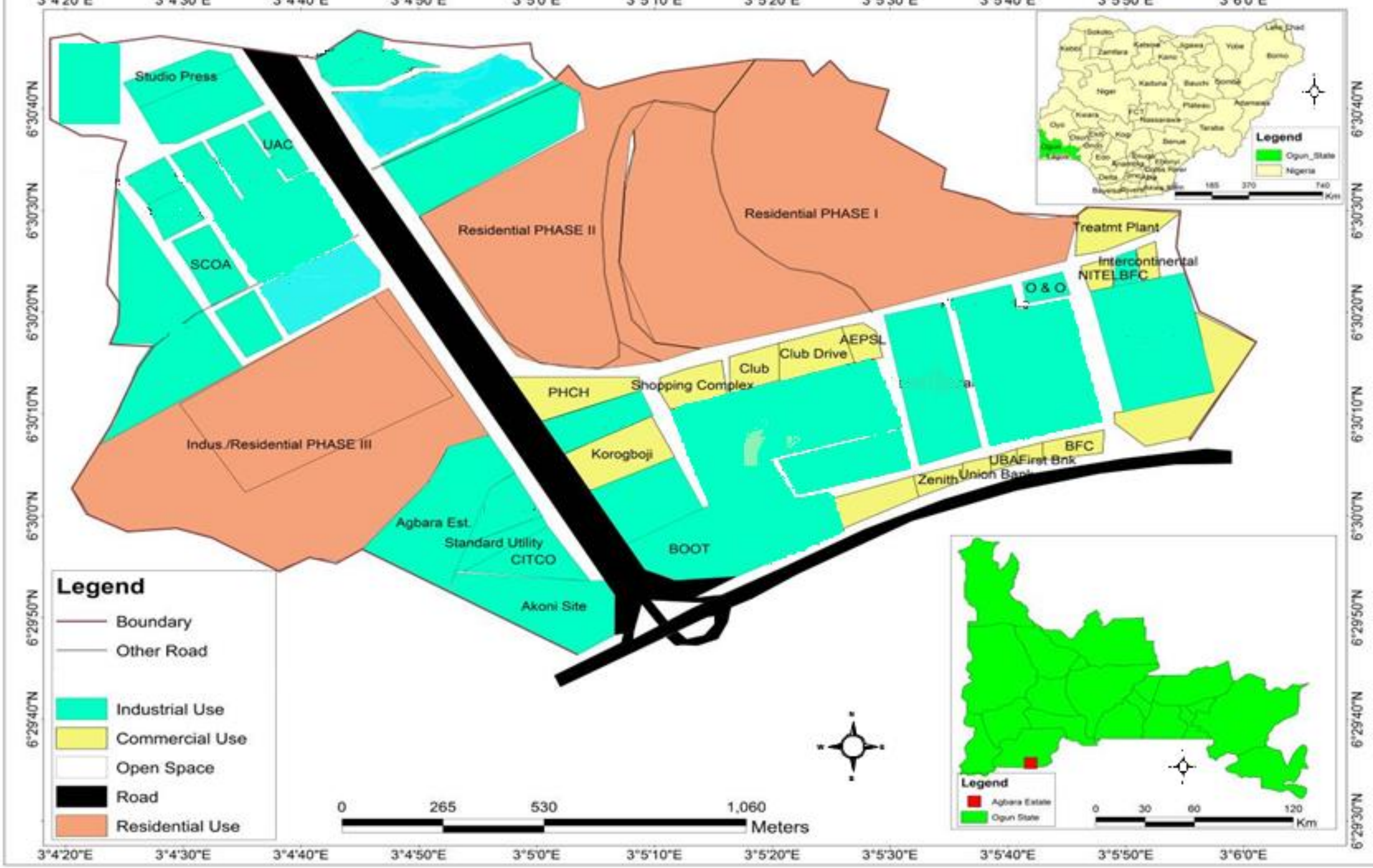

Fig 3.1: Agbara Estate, Ogun State, Nigeria

Source: Agbara Estate Limited, 2008

3.2.3 Socioeconomic activities

Agbara Estate consists of industrial, commercial, residential and recreational areas. The industrial areas constitute 41.55% (188.289 hectares) of the whole estate. The industrial area provides sites for a number of industrial concerns, many of which are members of multinational conglomerates, operating some of their most modern purpose built factories in the country (AEL, 2008). The study area is also an excellent mix of various types of manufacturing industries which fall into different sectoral groups according to the Manufacturers Association of Nigeria (MAN) industrial classification. These motives essentially informed why the study area was preferred for the study. As presented in Table 3.1, functional industries include food and beverage, plastics, chemicals, non metallic mineral products industries

3.3 Methodology

3.3.1 Reconnaissance survey

A reconnaissance survey was carried out in the study area order to acclimatize the researcher with the area. In the study, the researcher identified all the industries in the study area, distinguished the operational ones from those that are non-operational and also made an observation as to what each industry produces and the nature of its production (i.e. the volume and diversity of their products). This made the researcher to able to group the industries into different sectoral groups based on the MAN industrial classification.

3.3.2 Types of data

The study required the following types of data

i. List of all the stationary equipments that combust any kind of fossil fuel in the selected industries.

Table 3.1: List of the functional industries within the study area

SN	Industries	SN	Industries
1	Industry C	11	Industry I
2	Industry O	12	Industry L
3	Industry B	13	Industry K
4	Industry Q	14	Industry P
5	Industry F	15	Industry N
6	Industry M	16	Industry D
7	Industry G	17	Industry E
8	Industry A		
9	Industry H		
10	Industry J		

Source: AEL, 2008

ii. Activity data of the identified equipment/emission sources, this is basically the amount of the fuel combusted in the emission sources. This was obtained from fuel use/consumption records like fuel bills or fuel purchased receipts.

iii. IPCC's default CO_2 emission factors for all fuel types from the 2006 guideline version.

iv. Data on the provisions for emission monitoring and management.

3.3.3 Sources of data

The required data was sourced from both primary and secondary sources

3.3.3.1 *Primary source of data*

The primary data was sourced via physical field data collection and the use of CO_2 best management practices checklist. This is a primary source of information involving field observation and instrumentation.

3.3.3.2 *Secondary source of data*

The secondary data, that is, the corresponding default emission factors for each fuel type was sourced from the IPCC's emission factors data base (EFDB) available athttp://www.ipcc-nggip.iges.or.jp/EFDB/main.php. Other materials for literature review were obtained from the assessment reports of the IPCC, online journals and publications, books, conference proceedings of international organizations and so forth.

3.3.4 Sample selection

There are seventeen functioning industries in the study area and a total of five industries were selected for the study. The identities of the industries were concealed due to security reasons. A stratified random sampling method was adopted for the industries selection. The stratification of the industries was based on the MAN industrial classification. All the industries in the study area fall into five MAN industrial strata as shown in the Table 3.2. One industry from each sectoral group was randomly selected using dip in the basket method of random selection. Table 3.3 shows the selected industries and their corresponding sectoral groups.

3.3.5 Carbon emission measurement

The use of documented emission factors in measuring CO_2 emission was the adopted method in this work. This method was preferred because it is the recognized method of GHG measurement by the UNFCCC and more importantly it is the only method that can realistically estimate the CO_2 emission in the study area given the temporal scope of the study, the diversity of the emission sources and the available resources. In this regard, a 12 months' fuel consumption records of each emission source (stationary equipment that combust fossil fuel) from each selected industry was collated and examined. This provided the required information on the nature (type, volume and mass as the case may be) of the fossil fuel combusted in each emission source for the period under consideration. The CO_2 emitted from each source were then calculated by multiplying the monthly volume/mass (as the case may be) of the fossil fuel combusted within the studied duration with the appropriate emission factor. The tier 1 method of CO_2 was used due to the absence of country-specific (Nigeria) emission factors. The equation for estimating CO_2 emission from each source is represented as

$$\text{Emission}\,CO_{2,\,fuel} = \text{Fuel consumption}_{\,fuel} \times \text{Emission factor}\,CO_{2,\,fuel} \qquad 3.1$$

Table 3.2: Selection of industries

MAN industrial sectoral groups	Industries within each sectoral group	Selected industries for the study
Food, beverages and tobacco sectoral group	Industry A Industry B Industry C Industry D Industry E	Industry D
Chemical and pharmaceutical sectoral group	Industry F Industry G Industry H Industry I Industry J Industry K Industry L Industry M	Industry G
Domestic and industrial plastic product, rubber and foam sectoral group	Industry N Industry O	Industry N
Nonmetallic mineral product sectoral group	Industry P	Industry P
Basic metal, iron and steel and fabricated metal products sectoral group	Industry Q	Industry Q

Table 3.3: Selected industries and their corresponding sectoral group

SN	Selected industries for the study	MAN industrial sectoral groups
1	Industry D	Food, beverages and tobacco sectoral group
2	Industry N	Domestic and industrial plastic product, rubber and foam sectoral group
3	Industry P	Nonmetallic mineral product sectoral group
4	Industry Q	Basic metal, iron and steel and fabricated metal products sectoral group
5	Industry G	Chemical and pharmaceutical sectoral group

i. Emission$CO_{2,\,fuel}$ = Emissions of CO_2 by type of fuel (in metric tons of CO_2),

ii. Fuel consumption $_{fuel}$= Activity data that quantify the CO_2 emission, in this case it was the volume (in liters or m^3) or mass (tones) of the fossil fuel combusted in each emission source (as the case may be) for the period considered,

iii. Emission factor$CO_{2,\,fuel}$ = Default emission factor of CO_2 by type of fuel (tones CO_2/liter, tones CO_2/m^3or tones CO_2/tones). IPCC's default emission factors were used because of the absence of country-specific (Nigeria) factors.

Emissions from all the sources within each industry were then consolidated in order to come up with total industry emission using equation 3.2.

$$\text{EMISSION}CO_2 = \sum\nolimits_{fuels} \text{EMISSION}CO_{2,\,fuel} \qquad 3.2$$

CO_2 emission was however automatically calculated and completed using the GHG protocol established tool for stationary combustion version 4.1 (WRI, 2015).

The total amount of CO_2 emitted by the assessed industries was compared with the inclusion threshold (i.e. the maximum amount of CO_2 that can be emitted by an emitter/emission source before it can be included in an emission trading programme (International carbon action partnership ICAP, 2016)) of various emission management programmes around the world in order to see how significant they are. This is because Nigeria is a non-annex (developing nation) member party of the UNFCCC and as such, it is currently not required to reduce its GHG emissions, hence the country presently do not have any CO_2 emission regulation/standards/programme where a cap or a predetermined maximum allowable amount of CO_2 will be allocated to industries as a control measure to regulate CO_2 emission.

3.3.6 Assessment of carbon(iv) oxide management practices

The fourth objective was achieved via the use of a best practice checklist for greenhouse gas management. The best practices checklist adapted in this work was designed by the world wildlife fund for their low carbon manufacturing programme (World Wildlife Fund (WWF), 2014) aimed at reducing the carbon emissions generated by manufacturing facilities (WWF, 2014). The checklist is meant to assess how well an organization has established and implemented its greenhouse gas management system and how close is the organization to greenhouse gas management best practices. The checklist together with its scoring system was developed based on ISO 14001 standards for environmental management systems and it took cognizance of the following elements:

i. Greenhouse Gas (GHG) Policy

This element checked for the presence and clarity of the GHG policy of the organization. It also probes into knowing the extent of the senior management commitment to the policy, policy communication to the employees, publicity of the policy and so forth because they are all prerequisite for a successful GHG reduction programme. The element has a total of 6 criteria.

ii. GHG Targets and Management Programme

This element observed the presence of GHG emissions targets which is clearly defined and measurable, it also check for the presence of an effective management strategy put in place to achieve the target via a number of criteria.

iii. Implementation and Operation

This element checked for the roles and responsibilities of staff in the implementation and operation of the GHG management programme i.e. are they well defined, documented and communicated in order to facilitate effective GHG management? Are required resources provided by the top management necessary for the implementation and control of the greenhouse gas management system? Are relevant training and awareness activities carried out in order to execute greenhouse gas management programme successfully?

iv. Checking and Corrective Actions

This element check for the amendment of necessary actions and practices for the achievement of GHG targets whenever necessary and so forth.

The scoring of the greenhouse gas management checklist followed a 3-point mark system:

0= little or no evidence

1= some elements implemented

2 = fully implemented

The checklist was checked and scores were allocated for each element in the checklist based on the information provided by each industry representatives; plant managers, production managers, especially the environmental, health and safety (EHS) managers. Score of 0 was allocated in the items where there is little or no evidence to support it, score of 1 was allocated where the items are somewhat implemented and score of 2 where the items were fully implemented. At the end of the assessment the mark gained in each part of the checklist by each investigated industry was compiled and compared against the maximum score to determine how close each organization to

CO_2 emission management best practices was. The first and second element has a maximum of 12 score having 6 criteria, the third has 14 while the fourth has 8 making a total of 46 achievable scores.

3.3.7 Method of data analyses

i. *To identify CO_2 emission sources of the selected industries in the study area.*

The result of this objective was presented using table and bar charts. This allowed for the different kind of stationary CO_2 emission sources within each industry and the type of fossil fuels that were combusted in them to be well illustrated.

ii. *To identify the activity data of the identified emission sources.*

The 12-month fuel use records of each identified emission sources were analyzed with descriptive statistics.

iii. *To determine the amount of CO_2 emitted from the identified emission sources.*

CO_2 emitted from the different sources within each industry was tested using analysis of variance and independent sample T test to check for any significant difference(s) in the average emission of the sources within each industry. However, before these tests were carried out, relevant preliminary test of fulfillment of the assumptions of parametric statistic (test of normality of distribution and homogeneity of variances) were carried out. The normality of the data were confirmed by using the Shapirowilk test of normality (data are normally distributed when $p>0.05$), visual inspection of histogram, normal quantile-quantile (Q-Q) Plots and box plot as well as the skewness and kurtosis of the data. Levene's test of homogeneity of variance was used to determine the equality of variance of the data compared. In situations where the data were not normally distributed, the data were transformed using either the log or square root transformation (in consideration of the one that successfully normalized the data) and luckily enough all data that were not normal became normal after transformation, hence there was no need in using the non parametric versions of the tests. One way Analysis of variance (ANOVA) and the independent sample T test with "equality of variance assumed" were applied in situation where the variances of the data to be compared were confirmed to be homogenous and in situation where the data were not homogenous, the more robust Welch test was adopted instead of ANOVA and the independent sample T test with "equality of variance not assumed" was also adopted as the case may be. Tukey and Games Howell Post hoc tests were respectively used to follow up the ANOVA and Welch test in order to reveal the pair wise comparism of the significant difference(s) detected. All significance test were conducted at $P<0.05$.

Furthermore, the contribution of the different fuel types to CO_2 emissions was also compared using the same procedure. Thus, this provided a comprehensive understanding of the significant difference(s) between the different emission sources and fuel type to CO_2 emissions. SPSS statistical package and Microsoft excel statistic tool kit were used in carrying out the analysis.

iv. *To compare the management practices of each selected industry to carbon(iv) oxide management best practices.*

Simple descriptive statistics was used in analyzing the result of this objective.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the data collected and discussed the results. The presentation is systematically done in order to address the objectives of this study.

4.2 Identified Stationary CO_2 Emission Sources

Table 4.1 presents all the stationary CO_2 emission sources in each of the selected industry in the study area as well as the types of fossil fuel that were combusted during the period under study that is June 2015-May 2016. From the Table, a total of 58 stationary CO_2 emission sources were identified. These emission sources basically include the electricity generators (both gas and diesel fired), tri generation plants, industrial steam boilers, industrial ovens, furnaces, and so forth which are basically large CO_2 emitting sources. Also, only three types of fossil fuel namely, natural gas, automated gas oil and liquefied petroleum gas were combusted in the identified emission sources. Thus, this is in line with the conclusion of Bradshaw *et al* 2006 in the IPCC Special Report on Carbon dioxide Capture and Storage where it was stated that oil and gas are the primary fuels in the refining and chemical sectors (including manufacturing industries). .

The differences in the types and quantity of emission sources observed in these industries is are obviously down to the differences in their production processes as they process different raw materials, for example Industry P deals with large scale processing of non metallic materials for example, sand tar, soda ash, lime stone, culets and feldspar which are required to be heated to a temperature as high as 1500^0C as compared to Industry N which only deals with processing of petroleum products which require a comparatively low amount of heat.

Table 4.1: Identified emission sources in each of the assessed industries

Selected Industry	Industrial category	Identified emission sources		Type of fuel combusted in the sources
Industry N	Domestic and industrial plastic product, rubber and foam sectoral group	Ref		
		1	Two 2188 KVA Cummings gas generators	Natural gas
		2	Two 1450 KVA Cummings gas generators	Natural gas
		3	1279 KVA Cummings diesel generator	Automated Gas Oil (AGO)/ Diesel oil
		4	Two 1256 KVA Cummings diesel generators	Automated Gas Oil (AGO)/ Diesel oil
		5	90 KVA Cummings diesel generator	Automated Gas Oil (AGO)/ Diesel oil
Industry G	Chemical and pharmaceutical sectoral group	Ref		
		1	Three 1000KVA Caterpillar diesel generators.	Automated Gas Oil (AGO)/ Diesel oil
		2	Four 1500KVA Jenbacher gas generators.	Natural gas
		3	Two 4 tons per hour dual engine Babcock steam boilers.	Natural gas and AGO
		4	One 5 tons per hour dual engine Cochren steam boilers.	Natural gas and AGO
Industry Q	Basic metal, Iron and steel and fabricated metal products sectoral	Ref		
		1	Two 2250 KVA Cummins diesel generators	Automated Gas Oil (AGO)/ Diesel oil

	group	2	One 1400 KVA Cummins diesel generator	Automated Gas Oil (AGO)/ Diesel oil
		3	Three 2188 KVA gas generators.	Natural gas
		4	Two 1450 KVA Cummins gas generators	Natural gas
		5	One four tons per hour shell max steam boiler.	Natural gas
		6	One 5000 cans per minute internal bake oven	Natural gas and liquefied petroleum gas (LPG)
		7	One PIN oven	Natural gas and liquefied petroleum gas (LPG)
		8	One Dry off oven	Natural gas and liquefied petroleum gas (LPG)
Industry D	Food, beverages and tobacco sectoral group	Ref		
		1	One 10 tons/hour dual engine LOOS steam boiler	Natural gas and AGO.
		2	Two 15 tons/hour dual engine LOOS steam boilers	Natural gas and AGO.
		3	One 25 tons/hour dual engine LOOS steam boiler	Natural gas and AGO.
		4	Three 2000 KVA caterpillar diesel engines.	AGO
		5	Dual fired watsilla trigeneration plant with a power output of almost 8MW.	Natural gas and AGO.
Industry P	Nonmetallic mineral product sectoral group	Ref		
		1	Continuous glass furnace with a maximum pull of 200 tons of batch materials per day	Natural gas and AGO.

	(TPD).	
2	Continuous glass furnace with a maximum pull of 180 tons of batch materials per day (TPD).	Natural gas and AGO.
3	A 3.5 MW Ruston gas turbine	Natural gas
4	Seven annealing ovens (lehrs)	Natural gas and LPG
5	One 2100 KVA Cummins gas engine	Natural gas
6	Three 2000 KVA Perkins diesel engines	AGO
7	Working ends: flaming of crates and packaging.	Natural gas and LPG

Source: Author's field research, 2016

Also the scale of production is a contributing factor to these differences, for example due to the nature of the production processes, Industry P functions twenty four hours a day, seven days a week producing glass products as compared to industry like Industry G which could even decide to shut down production without any considerable harm to its production processes. As a result industries which process more energy intensive materials and which has a large scale of production will require more quantity of emission sources and ultimately more CO_2 emissions in order to sustain its production and vice versa.

Also as pinpointed by Bradshaw *et al* 2006 that in the power generation and industrial sectors, many sources have large emission volumes that make them amenable to the addition of CO_2 capture technology, it is obvious that these sources are large stationary sources that produces large volumes of CO_2. Hence there is a potential opportunity for these plants to be equipped with CO_2 capture plants to produce a source of high-purity CO_2 for subsequent storage (carbon sequestration).

4.3 Fuel Consumption Records of the Emission Sources in the Selected Industries

In this section, the amount of fuel consumed by each category of emission sources in each of the industries is presented and discussed.

Tables 4.2 to 4.6 present a monthly breakdown of the amount of natural gas in cubic meters, AGO/ diesel oil in litres and LPG in tones that were combusted by the different emission sources from all selected industries in the study area. As shown in Table 4.2, Industry N has two groups of CO_2 emission sources; the gas and diesel generators. It can be inferred from the Table that gas generators are the main sources used in powering the industry production processes and the diesel generators are merely for backup purposes when there are no gas supply to the industry.

Table 4.2: Monthly Natural gas and AGO consumption of the different emission sources for Industry N, June 2015-May 2016

Fuel combustion period	Natural gas consumption by emission source 1 and 2 in cubic meters (m^3)	AGO consumption by emission source 3,4 and 5 in liters (L)
June	404,251.30	25,686.00
July	495,544.82	0.00
August	467,277.97	0.00
September	450,237.86	0.00
October	286,594.80	3,837.00
November	359,340.78	0.00
December	389,413.27	0.00
January	252,586.27	1,980.00
February	259,099.15	1,001.00
March	252,133.20	13,200.00
April	138,809.18	55,000.00
May	83,563.01	78,101.00
Total	3,838,851.61	178,805.00
Average	319,904.30	14,900.42
Min	83,563.01	0.00
Max	495,544.82	78,101.00
Standard dev	129,909.29	25,786.10
Variance	16,876,423,006.67	664,922,978.63

Source: Author's field work, 2016

Source 1 and 2 = Gas generators

Source 3, 4 and 5 = Diesel generators

Table 4.3: Monthly Natural gas and AGO consumption of the different emission sources for Industry G, June 2015-May 2016

Fuel combustion period	Natural gas consumption by emission source 2 in cubic meters (m^3)	Automated gas oil consumption by emission source 1 in liters (L)	Natural gas and diesel consumption of emission source 3 and 4	
			Natural gas (m^3)	AGO (L)
June	512,500.00	88,191.00	3,178.00	546.00
July	772,300.00	41,549.00	4,788.00	0.00
August	3,300,000.00	446.00	12,240.00	0.00
September	13,478,000.00	0.00	13,680.00	0.00
October	1,139,900.00	0.00	8,640.00	0.00
November	956,900.00	0.00	5,040.00	0.00
December	1,177,800.00	0.00	6,840.00	0.00
January	1,107,700.00	0.00	4,840.00	0.00
February	1,021,700.00	3,273.00	3,620.00	250.00
March	1,185.00	2,673.00	6,120.00	0.00
April	848.00	56,664.00	4,320.00	258.00
May	398.00	160,964.00	2,440.00	1,540.00
Total	23,469,231.00	353,760.00	75,746.00	2,594.00
Average	1,955,769.25	29,480.00	6,312.17	216.17
Min	398.00	0.00	2,440.00	0.00
Max	13,478,000.00	160,964.00	13,680.00	1,540.00
Standard dev	3,734,097.22	50,644.39	3,532.97	451.06
Variance	13,943,482,013,707.80	2,564,854,695.27	12,481,859.24	203,458.52
% of total	99.68	99.27	0.32	0.73

Source: Author's field work, 2016

Source 2 = Gas generators

Source 1 = Diesel generators

Sources 3 and 4 = Steam boiler

Table 4.4: Monthly Natural gas, AGO and LPG consumption of the different emission sources for Industry Q, June 2015-May 2016

Fuel combustion period	Natural gas consumption by emission source 3 and 4 in cubic meters (m^3)	Automated gas oil (AGO)consumption by emission source 1 and 2 in liters (L)	Natural gas and LPG consumption of emission source 5,6,7 and 8	
			Natural gas (m^3)	LPG (tons)
June	169,386.00	240.00	30,162.00	5.14
July	270,798.00	340.00	31,466.00	3.27
August	238,975.00	280.00	23,578.00	15.43
September	456,828.00	300.00	76,169.00	0.00
October	424,382.00	240.00	57,959.00	0.00
November	384,017.00	370.00	47,958.00	0.00
December	374,295.00	895.00	41,445.00	0.00
January	352,395.00	6,935.00	44,304.00	4.08
February	191,679.00	80.00	7,305.00	5.63
March	168,562.00	180.00	46,972.00	2.45
April	116,256.00	114,570.00	56,001.00	5.02
May	32,869.00	305,759.00	9,526.00	13.67
Total	3,180,442.00	430,189.00	472,845.00	54.70
Average	265,036.83	35,849.08	39,403.75	4.56
Min	32,869.00	80.00	7,305.00	0.00
Max	456,828.00	305,759.00	76,169.00	15.43
Standard dev	133,650.73	91,075.61	20,117.75	5.16
Variance	17,862,518,779.42	8,294,767,256.45	404,724,022.57	26.58
% of total	87.06	100.00	12.94	100.00

Source: Author's field work, 2016

Source 3 and 4 = Gas generators

Source 1 and 2 = Diesel generators

Source 5, 6, 7 and 8 = Steam boiler and Ovens

Table 4.5 Monthly Natural gas and AGO consumption of the different emission sources for Industry D, June 2015-May 2016

Fuel combustion period	Natural gas consumption and AGO by emission source 5		Natural gas and AGO consumption by emission source 1,2 and 3		AGO consumption of emission source 4
2015-2016	Natural gas (m^3)	AGO (L)	Natural gas (m^3)	AGO (L)	AGO (L)
June	1164250.26	304600.00	87631.74	0.00	710734.00
July	1132496.08	101917.00	98477.92	0.00	407670.00
August	6926587.36	0.00	141359.02	0.00	54150.00
September	1621572.10	0.00	85345.90	0.00	72671.00
October	1589312.52	0.00	101445.48	0.00	110430.00
November	1440615.13	0.00	60025.64	0.00	91524.00
December	1465334.24	0.00	110293.96	0.00	40444.00
January	1417386.32	0.00	90471.48	0.00	69045.00
February	1593528.14	0.00	101714.58	0.00	202518.00
March	1049386.46	105952.00	91251.04	0.00	423811.00
April	998820.10	100572.00	75180.07	0.00	402108.00
May	265122.40	1336324.00	74853.61	0.00	0.00
Total	20,664,411.11	1,949,365.00	1,118,050.44	0.00	2,585,105.00
Average	1,722,034.26	162,447.08	93,170.87	0.00	215,425.42
Min	265,122.40	0.00	60,025.64	0.00	0.00
Max	6,926,587.36	1,336,324.00	141,359.02	0.00	710,734.00
Standard dev	1682159.346	380621.7357	20550.62194	0.00	219906.618
Variance	2.82966E+12	1.44873E+11	422328062.1	0.00	48358920636
% of total	94.87	42.99	5.13	0.00	57.01

Source: Author's field work, 2016

Source 5 = Tri-generation plant

Source 1, 2 and 3 = Steam boilers

Source 4 = Diesel generators

Table 4.6: Monthly Natural gas, AGO and LPG consumption of the different emission sources for Industry P, June 2015-May 2016

Fuel combustion period	Natural gas consumption and AGO by emission source 1 and 2		Natural gas consumption and LPG by emission source 4		Natural gas consumption of emission source 3	Natural gas consumption of emission source 5	AGO consumption of emission source 6	Natural gas consumption and LPG by emission source 7	
	Natural gas (m^3)	AGO (L)	Natural gas (m^3)	LPG (tons)	Natural gas (m^3)	Natural gas (m^3)	AGO (L)	Natural gas (m^3)	LPG (tons)
June	645,185.13	191,808.00	0.00	145.00	0.00	0.00	767,232.00	0.00	15.00
July	1,072,686.10	0.00	67,042.88	35.00	134,085.23	53,634.30	269,251.00	13,408.12	6.00
August	1,366,563.44	0.00	97,611.68	0.00	390,446.12	78,089.34	52,072.00	19,522.42	2.00
Sept	1,631,461.34	0.00	129,481.07	0.00	517,924.30	258,962.14	25,202.00	51,792.32	0.00
October	1,488,222.24	0.00	118,113.00	0.00	472,451.04	236,227.01	30,343.00	47,245.14	0.00
Nov	1,541,700.10	0.00	122,357.14	0.00	489,428.10	244,714.30	31,834.00	48,942.41	0.00
Dec	979,559.13	0.00	77,742.78	0.00	310,971.15	155,485.41	62,367.00	31,097.23	0.00
January	1,553,788.76	0.00	123,316.48	0.00	493,266.27	246,633.13	33,753.00	49,326.01	0.00
Feb	1,247,208.22	0.00	98,984.41	0.00	395,939.11	197,969.22	56,634.00	39,594.44	0.00
March	1,392,256.94	0.00	110,496.42	0.00	441,986.34	220,993.20	87,696.00	44,198.34	5.00
April	999,263.26	0.00	0.00	85.00	111,029.21	0.00	356,501.00	0.00	9.00
May	747,085.60	153,955.00	0.00	174.00	64,963.23	0.00	615,821.00	0.00	12.00
Total	14,664,980.26	345,763.00	945,145.86	439.00	3,822,490.10	1,692,708.05	2,388,706.00	345,126.43	49.00
Averag	1,222,081.69	28,813.58	78,762.16	36.58	318,540.84	141,059.00	199,058.83	28,760.54	4.08
Min	645,185.13	0.00	0.00	0.00	0.00	0.00	25,202.00	0.00	0.00
Max	1,631,461.34	191,808.00	129,481.07	174.00	517,924.30	258,962.14	767,232.00	51,792.32	15.00
St dev	328,950.00	67,776.22	50,924.75	63.02	188,892.78	107,019.95	254,627.02	21,032.65	5.35
Variance	108,208,104,219.64	4,593,616,352.27	2,593,329,764.74	3,971.90	35,680,483,469.03	11,453,270,014.70	64,834,920,144.88	442,372,234.78	28.63
% of total	68.30	12.64	4.40	89.96	17.80	7.88	87.36	1.61	10.04

Source: Author's field work, (2016)

Source 1 and 2 = Continuous glass furnaces
Source 4 = Annealing ovens (Lehrs)
Source 3 =Gas turbine
Source 5 = Gas generators
Source 6 = Diesel generators
Source 7 = Working end

In Industry G as shown in Table 4.3, three groups of CO_2 emission sources exist: gas generators (emission source 2), diesel generators (emission source 1), and steam boilers (emission sources 3 and 4). The steam boilers are dual fired boilers that is, they have two sets of engines; gas engine and diesel engine making them to be able to combust both natural gas and automated gas oil. A total of 23,544,977 m^3 of natural gas and 356,354L of diesel were combusted across all the emission sources in the industry. The bulk of the natural gas (99.68%) and diesel fuel (99.27%) were combusted by the gas generators and diesel generators respectively with only a fraction combusted by the steam boilers during the studied duration.

A total of 23,469,231 m^3 of natural gas was combusted in the gas generators during the studied period and an average of 1,955,769.25 m^3 was combusted on a monthly basis. This amount is far greater than the amount combusted in the steam boilers because the gas generators are much more fuel consuming and they are always used to power several processes in the factory. A total of 353,760L of diesel was combusted in the diesel generators which are used as a backup for the gas generators during the studied period and an average of 29,480L was combusted on a monthly basis. This is also far greater than what is combusted in the steam boilers as shown in Table 4.3.

As shown in Table 4.4, Industry Q has three groups of CO_2 emission sources namely, gas generators (source 3 and 4), diesel generators (source 1 and 2) and steam boiler and Ovens (source 5, 6, 7 and 8). In addition to diesel and natural gas, liquefied petroleum gas was also used as a source of fuel to power the industrial ovens which are used in drying the company's product at some stages in its production. In this company, the steam boiler combusts only natural gas while the ovens combust both natural gas and liquefied petroleum gas. A total of 3,653,287 m^3 of natural gas, 430,189L of diesel and 54.70 tones of LPG were combusted across all the emission sources in the industry. The gas generators consumed 87.06% of the natural gas supplied to this industry during the studied period.

Table 4.5 shows the monthly fuel consumption record of Industry D for the studied duration. Here as well, the emission sources are in three groups: Tri-generation plant (Source 5), Steam boilers (Source 1, 2 and 3) and Diesel generators (Source 4). A total of 21,782,461.55 m^3 of natural gas and 4,534,470L of diesel were supplied to the industry during the studied duration. Out of this figure, 94.87% of the natural gas was combusted in the tri generation plant and the diesel consumption is more evenly shared between the tri generation plant (42.99%) and the diesel generators (57.01%), therefore it is easy to conclude that the trigeneration plant (a cogeneration plant synchronized to produce electricity, hot water and chilled water from single fuel combustion) has the largest share of the fuel consumed in the industry.

Table 4.6 provides a one year monthly natural gas, AGO and LPG consumption of the different emission sources in Industry P. The CO_2 emission source in this industry is quite diverse when compared with those of the other assessed industries. This industry is also highly energy intensive considering the fuel consumption records as presented in the Table, it is explicit from this Table that a total of 21,470,450.70 m^3 of natural gas, 2,734,469L of diesel and 488 tones of LPG were combusted across the various emission sources in the industry. This Table also showed that the glass furnaces are responsible for combusting the largest percentage (68.30%) of the natural gas supplied to the industry within the studied duration and about 87.36% of diesel supplied was combusted in the diesel generators and the bulk (89.96%) of the liquefied petroleum gas was combusted by the annealing ovens (lehrs). It is also explicit from this table that natural gas is the major fuel that is used to run the industry production processes as AGO and LPG are only used as a backup fuel.

From the fuel consumption records of all the industries, it is clear that natural gas is preferred to diesel oil and other fossil fuel like black oil and LPG in powering the various industrial processes. There are some possible explanations for this. Firstly, is the fact that the whole industrial estate has a direct access to natural gas supply from Shell Nigeria (a major petrochemical industry in Nigeria), hence for these industries, natural gas supply is generally more reliable than liquid fuel supply in trucks because it is a continuous flow stream through the pipeline and what customers need do is to just open the valve. Secondly, there's no need for huge capital investment on storage facilities because natural gas flows from the wellhead through pipelines and processing systems to locations where it is required. The third explanation is that the natural gas supply is highly abundant and almost always available except in few situations of pipe line maintenance and vandalization. And more importantly is the fact natural gas is cheaper compared to all other fossil fuel types.

Natural gas being the major fuel used in running various industrial processes in the study area is preferable and better from the environmental point of view because had other fuel alternative is being used, the carbon foot print of these industries will have been way more than what it currently is. This is because of the fact that natural gas produces lower CO_2 emission at the same energy input when compared to other fossil fuel and it also has lesser impurities. Also, the fuel consumption pattern of the accessed facilities is likely to be different from other industries that do not have direct access to natural gas.

4.4 Quantity of CO_2 Emitted from the Different Emission Sources and Different Fuel Types

The result of the estimation of CO_2 from the identified emission sources in Industry N is shown in Table 4.7 A total of 7,714.65 tones of CO_2 were emitted from the identified sources

Table 4.7: Monthly breakdown of the estimated CO_2 emission from the different emission sources in Industry N

Fuel combustion period	Amount of CO_2 emitted from combustion of natural gas in source 1 and 2 (tones)	Amount of CO_2 emitted from combustion of AGO in source 3,4 and 5 (tones)
June	762.00	68.75
July	934.08	0.00
August	880.80	0.00
September	848.68	0.00
October	540.22	10.27
November	677.34	0.00
December	734.03	0.00
January	476.12	5.30
February	488.39	2.68
March	475.26	35.33
April	261.65	147.21
May	157.51	209.04
TOTAL	7236.08	478.57
Average	603.01	39.88
Abs total	7714.65	
% of total	93.80	6.20

Source: Author's field work, (2016)
Source 1 and 2 = Gas generators
Source 3, 4 and 5 = Diesel generators

during the assessed period and 93.80% of this amount was contributed by the combustion of natural gas in the gas generators while the 6.20% was contributed by the combustion of diesel in the diesel generators.

An independent sample T test was conducted to compare the significant differences in the amount of CO_2 emission between two identified major emission sources (combustion of natural gas in gas generators and AGO in diesel generators). The result presented in the Table 4.8 shows that there is statistical significant difference in the amount of CO_2 emission (MD=19.98452, SD=2.16937, $P<0.001$). The magnitude of the difference using Cohen's *d* (3.73) revealed that the average tones of CO_2 emitted as a result of combustion of natural gas in the gas generators is significantly larger than the average tones of CO_2 emitted from the combustion of automated gas oil in the diesel generators. Hence, this result proved that natural gas and natural gas combusting sources are basically responsible for CO_2 emission in this industry and as a result, any CO_2 reduction strategy to be adopted in this industry should be directed towards natural gas usage and natural gas combusting sources. Therefore, opportunities for reduction of this company emission lie within all the processes and activities that are being powered by natural gas in the industry.

Table 4.9 shows the result of the estimated amount of CO_2 emitted from the identified emission sources in Industry G. It is clear from this table that out of an absolute total of 45,055.45 tones of CO_2 emitted from all the identified sources, 44,238.56 tones (98.19%) was as a result of combustion of natural gas in the gas generators while 666.82 tones (1.48%) and 150.06 tones (0.33%) was contributed by the diesel and the steam boilers respectively. Table 4.10 presents the analysis of variance performed to investigate the significant difference in the amount of CO_2 emission between gas generators, diesel generators and steam boilers.

Table 4.8: Independent Samples Test of estimated CO_2 emission from the different emission sources in Industry N

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Emission	Equal variances assumed	.037	.850	9.212	22	.000	19.98452	2.16937	15.48552	24.48353
	Equal variances not assumed			9.212	21.872	.000	19.98452	2.16937	15.48399	24.48506

Table 4.9: Monthly breakdown of the estimated CO_2 emission from the different emission sources in Industry G

Fuel combustion period	Amount of CO_2 emitted from combustion of Natural gas in source 2 in tones	Amount of CO_2 emitted from combustion of AGO in source 1 in tones	Amount of CO_2 emitted from combustion of Natural gas and AGO in source 3and 4 in tones		
2015- 2016			Emission from Natural gas	Emission from AGO	Total emission
June	966.04	166.24	6.00	1.46	7.47
July	1,455.75	78.32	9.05	0.00	9.05
August	6,220.37	0.84	23.13	0.00	23.13
September	25,405.49	0.00	25.85	0.00	25.85
October	2,148.67	0.00	16.32	0.00	16.32
November	1,803.72	0.00	9.52	0.00	9.52
December	2,220.11	0.00	12.92	0.00	12.92
January	2,087.97	0.00	9.14	0.00	9.14
February	1,925.86	6.17	6.84	0.67	7.51
March	2.23	5.04	11.56	0.00	11.56
April	1.60	106.81	8.16	0.69	8.85
May	0.75	303.41	4.61	4.12	8.73
Total	44,238.56	666.82	143.12	6.94	150.06
Average	3,686.55	55.57	11.93	0.58	12.51
Abs total	45,055.45				
% of total	98.19	1.48			0.33

Source: Author's field work, (2016)
Source 2 = Gas generators
Source 1 = Diesel generators
Sources 3 and 4 = Steam boilers

Table 4.10: Homogeneity of variances/ANOVA/Welch test of estimated CO_2 emission from the different emission sources in Industry G

Test of Homogeneity of Variances

Emission

Levene Statistic	df1	df2	Sig.
11.798	2	33	.000

ANOVA

Emission

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	22.964	2	11.482	11.270	.000
Within Groups	33.621	33	1.019		
Total	56.585	35			

Robust Tests of Equality of Means

Emission

	Statistic[a]	df1	df2	Sig.
Welch	7.254	2	15.275	.006

a. Asymptotically F distributed.

The test revealed that there was statistical significant difference in the amount of CO_2 emission [$F(2, 15.275) = 7.254$, $P=0.006$].

Table 4.11 presents the Games Howell post hoc test conducted in order to know how the emissions from the sources are significantly different. The average CO_2 emission from the gas generators is significantly larger than the average emission from the diesel generators ($P=0.005$), while the average CO_2 emission from the gas generators is also significantly larger than the emission from the steam boilers ($P=0.007$). However, the average CO_2 emission from the diesel generators is not significantly different from the emission from the steam boilers ($P=0.742$). A partial eta square value of 0.406 (40.6%) revealed a huge magnitude of the differences where they exist.

The implication of this result is that the gas generators are overwhelmingly the dominant contributor of this company greenhouse gas footprint and any carbon reduction programme in this company should be focused on how emission from the gas generators can be reduced. Emissions from the diesel generators and the steam boilers may not require any management.

Also Table 4.12 presents a monthly breakdown of the number of tones of CO_2 emitted from the combustion of natural gas and diesel oil without regarding the source in which they were combusted. From the Table, it is clear that the bulk of CO_2 emitted from the identified emission sources in the industry was as a result of natural gas combustion, while only a minute fraction was due to automated gas oil combustion. An independent sample T test was conducted to compare the significant differences in the amount of CO_2 emission between natural gas and diesel oil combustion. The result presented in the Table 4.13 shows that there is statistical significant difference in the amount of CO_2 emission ($MD=1.94$, $SD=0.44$, $P<0.001$).

Table 4.11: Multiple Comparisons of estimated CO_2 emission from the different emission sources in Industry G

Dependent Variable: Emission
Games-Howell

(I) Emission	(J) Emission	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Source 2	Source 1	1.79290*	.50231	.005	.5207	3.0651
	Source 3 and 4	1.57440*	.41393	.007	.4610	2.6878
Source 1	Source 2	-1.79290*	.50231	.005	-3.0651	-.5207
	Source 3 and 4	-.21850	.29285	.742	-1.0031	.5661
Source 3 and 4	Source 2	-1.57440*	.41393	.007	-2.6878	-.4610
	Source 1	.21850	.29285	.742	-.5661	1.0031

*. The mean difference is significant at the 0.05 level.

Table 4.12: Monthly breakdown of the estimated CO_2 emission from the combustion of natural gas and automated gas oil in Industry G

Fuel combustion period	Amount of CO_2 emitted from combustion of Natural gas in tones	Amount of CO_2 emitted from combustion of AGO in tones
June	972.05	167.70
July	1,464.80	78.32
August	6,243.49	0.84
September	25,431.34	0.00
October	2,164.99	0.00
November	1,813.24	0.00
December	2,233.03	0.00
January	2,097.12	0.00
February	1,932.70	6.84
March	13.80	5.04
April	9.76	107.50
May	5.36	307.53
Total	44,381.68	673.77
Average	3,698.47	56.15
Abs total	45,055.45	
% of total	98.50	1.50

Source: Author's field work, (2016)

Table 4.13: Independent Samples Test of estimated CO_2 emission from the different fuel type combusted in Industry G

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Emission	Equal variances assumed	.060	.80	4.39	22	.000	1.94341	.44249	1.0257	2.8610
	Equal variances not assumed			4.392	21.54	.000	1.94341	.44249	1.02461	2.86220

The magnitude of the difference using Cohen's *d* (1.80) revealed that the average tones of CO_2 emitted as a result of combustion of natural gas is significantly larger than the average tones of CO_2 emitted from the combustion of automated gas oil. This means that natural gas has been and will continue to be the major contributor of the carbon foot print of this company and as a result CO_2 emission management of this company needs to be focused on natural gas consumption.

Table 4.14 presents a detailed monthly breakdown of the estimated CO_2 emitted from the different emission sources identified in Industry Q. It is obvious from the Table that about 8,200.94 tones of CO_2 were emitted from all the sources during the studied period and a huge percentage (73.10%) of this amount was as a result of combustion of fuel in the gas generators followed by the diesel generators (14.04%) and finally the steam boilers and ovens (12.86%). Table 4.15 presents the analysis of variance performed to investigate the significant difference in the amount of CO_2 emission between gas generators, diesel generators and steam boilers and Ovens. The test revealed that there was statistical significant difference in the amount of CO_2 emission [$F(2, 15.074) = 15.138$, $P<0.001$]. Games Howell post hoc test conducted as shown in Table 4.16 revealed that the average emission from the gas generators is significantly higher than the emission from the diesel generators ($P=0.002$), emission from the diesel generators is also significantly higher than the emission from the steam boiler and ovens ($P<0.001$). However, the post hoc test showed that there is no significant difference between the emissions from the diesel generators and the steam boilers and ovens ($P=0.993$). The magnitude of the partial eta square calculated was 0.494 (49.4%) indicating a large effect size.

Table 4.17 presents a monthly estimate of the number of tones of CO_2 emitted from the combustion of natural gas, diesel oil and liquefied petroleum gas in the various identified sources.

Table 4.14: Monthly breakdown of the estimated CO_2 emission from the different emission sources in Industry Q

Fuel combustion period	Amount of CO_2 emitted from combustion of natural gas in source 3 and 4 in tones	Amount of CO_2 emitted from combustion of AGO in source 1 and 2 in tones	CO_2 emitted from combustion of natural and Liquefied petroleum gas in source 5,6,7,and 8 in tones		
			Emission form Natural gas	Emission from LPG	Total emission
June	319.29	0.64	56.85	15.35	72.21
July	510.44	0.91	59.31	9.77	69.08
August	450.46	0.75	44.44	46.06	90.50
September	861.10	0.80	143.58	0.00	143.58
October	799.94	0.64	109.25	0.00	109.25
November	723.86	0.99	90.40	0.00	90.40
December	705.53	2.40	78.12	0.00	78.12
January	664.25	18.56	83.51	12.18	95.69
February	361.31	0.21	13.77	16.80	30.57
March	317.73	0.48	88.54	7.31	95.85
April	219.14	306.65	105.56	14.98	120.54
May	61.96	818.36	17.96	40.79	58.75
Total	5,995.01	1,151.40	891.29	163.25	1,054.54
Average	499.58	95.95	74.27	13.60	87.88
Abs total	8,200.94				
% of total	73.10	14.04			12.86

Source: Author's field work, (2016)
Source 3 and 4 = Gas generators
Source 1 and 2 = Diesel generators
Source 5, 6, 7 and 8 = Steam boiler and Ovens

Table 4.15: Homogeneity of variances/ANOVA/Welch test of estimated CO_2 emission from the different emission sources in Industry Q.

Test of Homogeneity of Variances

Emission

Levene Statistic	df1	df2	Sig.
7.089	2	33	.003

ANOVA

Emission

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1329952.179	2	664976.090	16.120	.000
Within Groups	1361344.594	33	41252.866		
Total	2691296.773	35			

Robust Tests of Equality of Means

Emisssion

	Statistic[a]	df1	df2	Sig.
Welch	15.138	2	15.074	.000

a. Asymptotically F distributed.

Table 4.16: Multiple Comparisons of estimated CO_2 emission from the different emission sources in Industry Q

Dependent Variable: Amountemitted
Games-Howell

(I) EmissionSS	(J) EmissionSS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
source 3 and 4	source 1and 2	403.63500*	101.19565	.002	149.4056	657.8644
	source 5,6,7 and 8	411.70583*	73.22226	.000	214.7232	608.6885
source 1and 2	source 3 and 4	-403.63500*	101.19565	.002	-657.8644	-149.4056
	source 5,6,7 and 8	8.07083	70.88283	.993	-182.5685	198.7102
source 5,6,7 and 8	source 3 and 4	-411.70583*	73.22226	.000	-608.6885	-214.7232
	source 1and 2	-8.07083	70.88283	.993	-198.7102	182.5685

*. The mean difference is significant at the 0.05 level.

Table 4.17: Monthly breakdown of the estimated CO_2 emission from the combustion of natural gas, automated gas oil and liquefied petroleum gas in Industry Q

Fuel combustion period	Amount of CO_2 emitted from combustion of natural gas in tones	Amount of CO_2 emitted from combustion of AGO in tones	Amount of CO_2 emitted from combustion of LPG in tones
June	376.14	0.64	15.35
July	569.76	0.91	9.77
August	494.90	0.75	46.06
September	1,004.68	0.80	0.00
October	909.19	0.64	0.00
November	814.26	0.99	0.00
December	783.65	2.40	0.00
January	747.76	18.56	12.18
February	375.08	0.21	16.80
March	406.27	0.48	7.31
April	324.70	306.65	14.98
May	79.91	818.36	40.79
Total	6,886.30	1,151.40	163.25
Average	573.86	95.95	13.60
Abs total	8,200.94		
% of total	83.97	14.04	1.99

Source: Author's field work, (2016)

Out of a total of 8,200.94 tones of CO_2 emitted, 83.97% of the amount was as a result of combustion of natural gas, 14.04% was from automated gas oil and 1.99% was from liquefied petroleum gas. One way ANOVA was performed to investigate the significant differences in the amount of CO_2 emission between the combustion of Natural gas, AGO and LPG. The ANOVA test revealed (as shown in Table 4.18) that there was a statistical significant differences in the amount of CO_2 emission [$F (2, 33) =35.55$, $P<0.001$ at $P<0.05$ sig level]. The Tukey post hoc test conducted as shown in Table 4.19 showed that emission from natural gas combustion is significantly higher than emission from AGO combustion ($P<0.001$), average emission from natural gas is significantly higher than the average emission from LPG ($P<0.001$). However, the test revealed that the average emission from AGO is not significantly different from the average emission from LPG ($P=0.732$) during the assessed period. The magnitude of the differences is large as revealed by the partial eta square value of 0.683(68.3%). Therefore, in this company as well, natural gas and natural gas combusting sources are responsible for the majority of the CO_2 emitted and as a result opportunities to reduce CO_2 emission in this company lie in the various industrial activities that are being powered by natural gas.

Table 4.20 illustrates a monthly breakdown of the estimated CO_2 emitted from the different emission sources identified in Industry D. A total of 53,195.54 tones of CO_2 were emitted from the different emission sources, of which the trigeneration plant was responsible for 44,169.05 tones of CO_2 (83.03%). This was not unexpected because the plant is the central source from which the bulk of the energy (electricity and heat) used in powering the various companies' production processes is being generated. The diesel generators followed the trigeneration plant in term of amount of CO_2 emitted (13.01%) and the steam boilers contributed least (3.96%). The ANOVA test as shown in Table 4.21 revealed that there was a statistical significant differences in the amount of CO_2 emission [$F (2, 14.944) = 36.474$, $P< 0.001$].

Table 4.18: Homogeneity of variances/ANOVA of estimated CO_2 emission from the different fuel type combusted in Industry Q

Test of Homogeneity of Variances

Emission

Levene Statistic	df1	df2	Sig.
3.141	2	33	.056

ANOVA

Emission

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2996.516	2	1498.258	35.552	.000
Within Groups	1390.695	33	42.142		
Total	4387.211	35			

Table 4.19: Multiple Comparisons of estimated CO_2 emission from the different fuel types combusted in Industry Q

Dependent Variable: Emission
Tukey HSD

(I) Type of fuel	(J) Type of fuel	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Natural gas	AGO	18.27330*	2.65023	.000	11.7702	24.7764
	LPG	20.27799*	2.65023	.000	13.7749	26.7811
AGO	Natural gas	-18.27330*	2.65023	.000	-24.7764	-11.7702
	LPG	2.00469	2.65023	.732	-4.4984	8.5078
LPG	Natural gas	-20.27799*	2.65023	.000	-26.7811	-13.7749
	AGO	-2.00469	2.65023	.732	-8.5078	4.4984

*. The mean difference is significant at the 0.05 level.

Table 4.20: Monthly breakdown of the estimated CO_2 emission from the different emission sources in Industry D

Fuel combustion period	Amount of CO_2 emitted from combustion of natural gas and AGO in source 5 in tones			Amount of CO_2 emitted from combustion of natural gas and AGO in source 1,2 and 3 in tones			Amount of CO_2 emitted from combustion of AGO in source 4 in tones
	Emission from Natural gas	Emission from AGO	Total emission	Emission form Natural gas	Emission from AGO	Total emission	
June	2,194.57	815.26	3,009.82	165.18	0.00	165.18	1,902.27
July	2,134.71	272.78	2,407.49	185.63	0.00	185.63	1,091.13
August	13,056.34	0.00	13,056.34	266.46	0.00	266.46	144.93
September	3,056.60	0.00	3,056.60	160.87	0.00	160.87	194.50
October	2,995.79	0.00	2,995.79	191.22	0.00	191.22	295.57
November	2,715.50	0.00	2,715.50	113.15	0.00	113.15	244.96
December	2,762.10	0.00	2,762.10	207.90	0.00	207.90	108.25
January	2,671.72	0.00	2,671.72	170.54	0.00	170.54	184.80
February	3,003.74	0.00	3,003.74	191.73	0.00	191.73	542.04
March	1,978.05	283.58	2,261.63	172.00	0.00	172.00	1,134.33
April	1,882.74	269.18	2,151.92	141.71	0.00	141.71	1,076.24
May	499.75	3,576.66	4,076.41	141.10	0.00	141.10	0.00
Total	38,951.59	5,217.46	44,169.05	2,107.48	0.00	2,107.48	6,919.01
Average	3,245.97	434.79	3,680.75	175.62	0.00	175.62	576.58
Abs total	53,195.54						
% of total			83.03			3.96	13.01

Source: Author's field work, (2016)
Source 5 = Tri-generation plant
Source 1, 2 and 3 = Steam boilers
Source 4 = Diesel generators

Table 4.21: Homogeneity of variances/ANOVA/Welch test of estimated CO_2 emission from the different emission sources in Industry D

Test of Homogeneity of Variances

Emission

Levene Statistic	df1	df2	Sig.
4.071	2	33	.026

ANOVA

Emission

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13873.477	2	6936.738	42.153	.000
Within Groups	5430.556	33	164.562		
Total	19304.032	35			

Robust Tests of Equality of Means

Emission

	Statistic[a]	df1	df2	Sig.
Welch	36.474	2	14.944	.000

a. Asymptotically F distributed.

A Games Howell post hoc test conducted in order to know where exactly the differences lies as shown in Table 4.22 revealed that the average emission from the tri generation plant is significantly higher than the emission from the steam boilers ($P<0.001$), emission from the plant is also significantly higher than the emission from the diesel generators ($P<0.001$), however, there is no significant difference between the average emission of the diesel generators and the steam boilers ($P=0.139$). The magnitude of the effect size using partial eta square was 0.719(71.9%) which indicate a large effect size.

Table 4.23 also presents an illustration of the amount of CO_2 emitted based on the type of fuel combusted. It is glaring from the table that 77.19% of all the emissions comes from the combustion of natural gas while 22.81% comes from the combustion of diesel oil. An in dependent sample T test conducted to compare the significant difference in the amount of CO_2 emission between Natural gas and AGO. The result presented in Table 4.24 shows that there is statistical significant difference in the amount of CO_2 emission [$MD=0.704$, $SD=0.174$, $P=0.001$]. The magnitude of the difference using Cohen's *d* is 1.65 indicating a large effect size.

Table 4.25 displays a monthly breakdown of the estimated CO_2 emitted from the different emission sources identified in Industry P. A total of 49,247.78 tones of CO_2 were emitted across the various sources in the industry during the assessed period. Out of these values, the continuous glass furnaces contributed the highest percentage 58.01% and the rest sources contributed less as shown in the Table. The ANOVA as revealed in Table 4.26 showed that there was a statistical significant differences in the amount of CO_2 emission [$F\ (5, 26.503) = 59.945$, $P< 0.001$]. A Games Howell post hoc test conducted as revealed in Table 4.27, showed that the average emission from the continuous glass furnaces is significantly higher than the average emission from all other emission sources in the industries with $P<0.001$ in all cases.

Table 4.22: Multiple Comparisons of estimated CO_2 emission from the different emission sources in Industry D

Dependent Variable: Emission
Games-Howell

(I) Emission	(J) Emission	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Source 5	Source 1,2 and 3	44.91622*	5.28600	.000	30.6652	59.1672
	Source 4	37.32703*	6.40071	.000	21.1027	53.5513
Source 1,2 and 3	Source 5	-44.91622*	5.28600	.000	-59.1672	-30.6652
	Source 4	-7.58919	3.65653	.139	-17.4281	2.2497
Source 4	Source 5	-37.32703*	6.40071	.000	-53.5513	-21.1027
	Source 1,2 and 3	7.58919	3.65653	.139	-2.2497	17.4281

*. The mean difference is significant at the 0.05 level.

Table 4.23: Monthly breakdown of the estimated CO_2 emission from the combustion of natural gas and automated gas oil in Industry D

Fuel combustion period	Amount of CO_2 emitted from combustion of natural gas in tones	Amount of CO_2 emitted from combustion of AGO in tones
June	2,359.75	2,717.53
July	2,320.34	1,363.91
August	13,322.80	144.93
September	3,217.47	194.50
October	3,187.01	295.57
November	2,828.65	244.96
December	2,970.00	108.25
January	2,842.25	184.80
February	3,195.46	542.04
March	2,150.06	1,417.91
April	2,024.45	1,345.42
May	640.84	3,576.66
Total	41,059.07	12,136.47
Average	3,421.59	1,011.37
Abs total	53,195.54	
% of total	77.19	22.81

Source: Author's field work, (2016)

Table 4.24: Independent Samples Test of estimated CO_2 emission from the different fuel type combusted in Industry D

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Emission	Equal variances assumed	10.271	.004	4.048	22	.001	.70450	.17402	.34360	1.06541
	Equal variances not assumed			4.04	17.0	.001	.70450	.17402	.3374	1.0715

Table 4.25: Monthly breakdown of the estimated CO_2 emission from the different emission sources in Industry P

Fuel combustion period	Amount of CO_2 emitted from combustion of natural gas and AGO in source 1 and 2 in tones			Amount of CO_2 emitted from combustion of natural and Liquefied petroleum gas in source 4 in tones			Amount of CO_2 emitted from combustion of Natural gas in source 3 in tones	Amount of CO_2 emitted from combustion of Natural gas in source 5 in tones	Amount of CO_2 emitted from combustion of AGO in source 6 in tones	Amount of CO_2 emitted from combustion of natural and Liquefied petroleum gas in source 7 in tones		
	Emission from Natural gas	Emission from AGO	Total emission	Emission form Natural gas	Emission from LPG	Total emission				Emission form Natural gas	Emission from LPG	Total emission
June	1,216.15	513.37	1,729.52	0.00	432.77	432.77	0.00	0.00	2,053.49	0.00	44.77	44.77
July	2,021.97	0.00	2,021.97	126.37	104.46	230.84	252.75	101.10	720.65	25.33	17.91	43.24
Aug	2,575.92	0.00	2,575.92	183.99	0.00	183.99	735.98	147.20	139.37	36.89	5.97	42.86
Sept	3,075.24	0.00	3,075.24	244.07	0.00	244.07	976.27	488.13	67.45	97.86	0.00	97.86
Oct	2,805.24	0.00	2,805.24	222.64	0.00	222.64	890.55	445.28	81.21	89.27	0.00	89.27
Nov	2,906.04	0.00	2,906.04	230.64	0.00	230.64	922.55	461.28	85.20	92.47	0.00	92.47
Dec	1,846.43	0.00	1,846.43	146.54	0.00	146.54	586.17	293.08	166.92	58.76	0.00	58.76
Jan	2,928.83	0.00	2,928.83	232.45	0.00	232.45	929.79	464.89	90.34	93.20	0.00	93.20
Feb	2,350.94	0.00	2,350.94	186.58	0.00	186.58	746.33	373.16	151.58	74.81	0.00	74.81
Mar	2,624.35	0.00	2,624.35	208.28	0.00	208.28	833.13	416.56	234.72	83.51	14.92	98.43
April	1,883.57	0.00	1,883.57	0.00	253.69	253.69	209.29	0.00	954.17	0.00	26.86	26.86
May	1,408.23	412.06	1,820.29	0.00	519.33	519.33	122.45	0.00	1,648.24	0.00	35.82	35.82
Total	27,642.90	925.43	28,568.33	1,781.56	1,310.25	3,091.81	7,205.24	3,190.69	6,393.35	652.10	146.25	798.35
Average	2,303.58	77.12	2,380.69	148.46	109.19	257.65	600.44	265.89	532.78	54.34	12.19	66.53
Abs total	49,247.78											
% of total			58.01			6.28	14.63	6.48	12.98			1.62

Source: Author's field work,(2016)

Source 1 and 2 = Continuous glass furnaces
Source 4 = Annealing ovens (Lehrs)
Source 3 =Gas turbine
Source 5 = Gas generators
Source 6 = Diesel generators
Source 7 = Working ends

Table 4.26: Homogeneity of variances/ANOVA/Welch test of estimated CO_2 emission from the different emission sources in Industry P.

Test of Homogeneity of Variances

Emission

Levene Statistic	df1	df2	Sig.
13.692	5	66	.000

ANOVA

Emission

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	43757802.852	5	8751560.570	58.795	.000
Within Groups	9823954.498	66	148847.795		
Total	53581757.350	71			

Robust Tests of Equality of Means

Emission

	Statistic[a]	df1	df2	Sig.
Welch	59.945	5	26.503	.000

a. Asymptotically F distributed.

Table 4.27: Multiple Comparisons of estimated CO_2 emission from the different emission sources in Industry P

Dependent Variable: Emission
Games-Howell

(I) Emission	(J) Emission	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Source 1 and 2	Source 4	2123.04333*	147.31659	.000	1628.3971	2617.6895
	Source 3	1780.25667*	176.91176	.000	1223.8995	2336.6138
	Source 5	2114.80500*	155.32000	.000	1607.8817	2621.7283
	Source 6	1847.91667*	243.79817	.000	1082.1875	2613.6458
	Source 7	2314.16583*	144.20360	.000	1822.9098	2805.4219
Source 4	Source 1 and 2	-2123.04333*	147.31659	.000	-2617.6895	-1628.3971
	Source 3	-342.78667	107.39487	.062	-698.9160	13.3426
	Source 5	-8.23833	66.03173	1.000	-219.7304	203.2537
	Source 6	-275.12667	199.18191	.737	-948.5264	398.2730
	Source 7	191.12250*	32.10241	.001	83.8598	298.3852
Source 3	Source 1 and 2	-1780.25667*	176.91176	.000	-2336.6138	-1223.8995
	Source 4	342.78667	107.39487	.062	-13.3426	698.9160
	Source 5	334.54833	118.13460	.099	-42.3114	711.4081
	Source 6	67.66000	221.96628	1.000	-644.4040	779.7240
	Source 7	533.90917*	103.08327	.003	183.0968	884.7215
Source 5	Source 1 and 2	-2114.80500*	155.32000	.000	-2621.7283	-1607.8817
	Source 4	8.23833	66.03173	1.000	-203.2537	219.7304
	Source 3	-334.54833	118.13460	.099	-711.4081	42.3114
	Source 6	-266.88833	205.17203	.780	-947.9687	414.1920
	Source 7	199.36083*	58.75960	.050	.2460	398.4757
Source 6	Source 1 and 2	-1847.91667*	243.79817	.000	-2613.6458	-1082.1875
	Source 4	275.12667	199.18191	.737	-398.2730	948.5264
	Source 3	-67.66000	221.96628	1.000	-779.7240	644.4040
	Source 5	266.88833	205.17203	.780	-414.1920	947.9687
	Source 7	466.24917	196.89067	.246	-204.8297	1137.3280
Source 7	Source 1 and 2	-2314.16583*	144.20360	.000	-2805.4219	-1822.9098
	Source 4	-191.12250*	32.10241	.001	-298.3852	-83.8598
	Source 3	-533.90917*	103.08327	.003	-884.7215	-183.0968
	Source 5	-199.36083*	58.75960	.050	-398.4757	-.2460
	Source 6	-466.24917	196.89067	.246	-1137.3280	204.8297

*. The mean difference is significant at the 0.05 level.

The test also revealed that average emission from the annealing ovens is not significantly different from that of all other sources except from that of the working ends (source 7) where it is significantly higher (P=0.001) and glass furnaces where it is significantly lower. Average emission from the gas turbines is not significantly different from that of the gas and diesel generators (P=0.099, P=1.00 respectively), however a significant difference exist when compared to that of the working ends (P=0.003). The average emission from the gas generators is not significantly different when compared with that of the diesel generators (P=0.78) and working ends (P=0.50). Finally, no significant difference exists between the average emission from the diesel generators and the working ends during the studied period (P=0.246). The magnitude of the differences using partial eta square was 0.817 (81.7%) indicating a large effect size.

Table 4.28 however, presents an illustration of the amount of CO_2 emitted based on the type of fuel combusted. It is clear from the table that 82.18% of all the emissions come from the combustion of natural gas while 14.86% comes from the combustion of diesel oil and 2.96% comes from the combustion of LPG. The ANOVA conducted revealed a statistical significant differences in the amount of CO_2 emission [F (2, 15.794) = 37.431, P<0.001] as shown in Table 4.29.

Games Howell post hoc test conducted as shown in Table 4.30 revealed that a significant difference exist between the average emission from natural gas combustion and AGO (P<0.001), average emission from natural gas and LPG (P<0.001). However there is no significant difference in the average emission from AGO and that of LPG (P=0.17). Partial eta square revealed a large effect size 0.736 (73.6%).

Table 4.28: Monthly breakdown of the estimated CO_2 emission from the combustion of natural gas, automated gas oil and liquefied petroleum gas in Industry P

Fuel combustion period	Amount of CO_2 emitted from combustion of natural gas in tones	Amount of CO_2 emitted from combustion of AGO in tones	Amount of CO_2 emitted from combustion of LPG in tones
June	1,216.15	2,566.86	477.54
July	2,527.52	720.65	122.37
August	3,679.97	139.37	5.97
September	4,881.57	67.45	0.00
October	4,452.98	81.21	0.00
November	4,612.99	85.20	0.00
December	2,930.98	166.92	0.00
January	4,649.16	90.34	0.00
February	3,731.82	151.58	0.00
March	4,165.83	234.72	14.92
April	2,092.86	954.17	280.56
May	1,530.68	2,060.30	555.14
Total	40,472.49	7,318.78	1,456.50
Average	3,372.71	609.90	121.37
Abs total	49,247.78		
% of total	82.18	14.86	2.96

Source: Author's field work, (2016)

Table 4.29: Homogeneity of variances/ANOVA/Welch of estimated CO_2 emission from the different fuel type combusted in Industry P

Test of Homogeneity of Variances

Emission

Levene Statistic	df1	df2	Sig.
12.723	2	33	.000

ANOVA

Emission

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	73771825.607	2	36885912.804	46.003	.000
Within Groups	26459975.570	33	801817.442		
Total	100231801.177	35			

Robust Tests of Equality of Means

Emission

	Statistic[a]	df1	df2	Sig.
Welch	37.431	2	15.794	.000

a. Asymptotically F distributed.

Table 4.30: Multiple Comparisons of estimated CO_2 emission from the different fuel types combusted in Industry P.

Dependent Variable: Emission
Games-Howell

(I) Fuel_type	(J) Fuel_type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Natural gas	AGO	2762.81167*	443.86890	.000	1635.7458	3889.8776
	LPG	3251.33417*	374.45284	.000	2247.1051	4255.5633
AGO	Natural gas	-2762.81167*	443.86890	.000	-3889.8776	-1635.7458
	LPG	488.52250	252.33746	.170	-182.8299	1159.8749
LPG	Natural gas	-3251.33417*	374.45284	.000	-4255.5633	-2247.1051
	AGO	-488.52250	252.33746	.170	-1159.8749	182.8299

*. The mean difference is significant at the 0.05 level.

The results show that all of assessed facilities as well as other facilities in the study have a similar pattern in their CO_2 emission, this is in the sense that natural gas and natural gas combusting sources are overwhelmingly the dominant contributor to the CO_2 emissions. This is because these companies have direct access to cheap and verily available natural gas and many of the companies have built and developed their processes around this source of fuel. Therefore, CO_2 emission management of these industries needs to be focused on natural gas usage. This pattern of emission where natural gas is the dominant contributor to CO_2 emission may likely be different from other industries that do not have direct access to natural gas.

Furthermore, even though these companies basically rely on natural gas which is a much more environmental friendly fossil fuel when compared with other fuel alternatives, they still emit a significant amount of CO_2 from their stationary installations annually. Industry N emitted a total of 7714.65 tones of CO_2, Industry G emitted 45,055.45 tones of CO_2, Industry Q emitted 8,200.94 tones of CO_2, Industry D emitted 53,195.54 tones of CO_2 and Industry P emitted 49,247.78 tones of CO_2 during the studied period. These figures are large figures that would be required to be reduced over time in many carbon management programmes around the world. For example, these figures are way beyond the "*inclusion threshold*" of many carbon management programmes around the world. Inclusion threshold (IT) is the maximum amount of CO_2 that can be emitted by an emitter/emission source before it can be included in an emission trading programme (International carbon action partnership ICAP, 2016). Comparing the emissions of the assessed industries with the inclusion thresholds of these programmes (Québec Cap-and Trade System in Canada, Korea Emissions Trading Scheme, Swiss ETS, California Cap-and-Trade Program-USA (IT $\geq$25,000tCO_2e (metric) per data year), Beijing pilot system-China (IT>10,000t CO_2e/year), Guangdong pilot system in China (IT>20,000 tCO_2e/year) and

EU Emissions Trading System (EU ETS) (IT Varies with included sectors but are all typically >10,000 t CO_2e/year),), it is clear that apart from the emission of Industry N and Industry Q that are lower than the thresholds, other studied companies emission in Agbara Estate are higher. It is worthy to note that the emissions from Industry N and Industry Q are much likely to be higher than these thresholds when emissions from other sources (non stationery emission and other GHG gases) are included. It is also noteworthy to mention that, Nigeria is a non-annex (developing nation) member party of the UNFCCC and as such, it is currently not required to reduce its GHG emissions, hence the country presently do not have any CO_2 emission regulation/standards/programme where a cap or a predetermined maximum allowable amount of CO_2 is allocated to industries as a control measure to regulate emission. Therefore there is no locally developed emission cap to compare these figures (emissions from the different assessed industries) with.

4.5 Best Practices for Carbon(iv) Oxide Management of Selected Industries

Table 4.31 shows the checked Greenhouse Gas Management Best Practices Checklist designed to assess how close each of the assessed organization is to CO_2 emission best practices. Each of the industries chosen for the study was assessed based on the several items contained in the checklist. As for the first element of the checklist; the presence of CO_2/ energy policy, out of a total of 12 achievable score, Industry N had 6, Industry G had 5, Industry Q had 0, Industry D 8 and Industry P had 6. This showed that apart from Industry Q and Industry G that have got a low score, the other companies had a fair to good performance in this element. The reason which made Industry Q to have a very low score is that the company became operational not too long ago and it is still in the process of developing its environmental management system.

Table 4.31: Comparison of selected industries' CO_2 management to global best practices

REF	ITEM	ASSESSMENT CRITERIA	INDUSTRIES					REMARKS
			INDUSTRY P	INDUSTRY Q	INDUSTRY G	INDUSTRY N	INDUSTRY D	
1.	**CO_2/ ENERGY POLICY**							
1.1	CO_2 policy statement.	Availability of a clear policy statement on CO_2 emissions pertaining to industry's activities.	□0 ■1 □2	■0 □1 □2	□0 ■1 □2	□0 ■1 □2	□0 ■1 □2	None of the assessed industries has clear policy statement meant to tackle the emission of CO_2 specifically. However, four of them have an energy reduction commitment which is spelt out has a separate policy or embedded within a general environmental management system. Only Industry Q currently has no policy for its energy management.
1.2	Applicable to all company activities.	Total coverage of industrial activities by the CO_2/ Energy policy.	□0 □1 ■2	■0 □1 □2	□0 □1 ■2	□0 □1 ■2	□0 □1 ■2	The energy policy of the industries that have it covers all the activities it is engaged in i.e. Activities in the offices, production units. e.t.c.
1.3	Senior management commitment.	Demonstration of senior management commitment to manage energy use / CO_2 emission at the facility level by the CO_2 / Energy policy.	■0 □1 □2	■0 □1 □2	■0 □1 □2	□0 ■1 □2	□0 □1 ■2	Four of the assessed industries have little or no evidence to showcase their senior management commitment. However one industry clearly showcases its senior management commitment to energy management in its yearly energy audit reports.
1.4	Policy communicated to employees.	Awareness of CO_2 / Energy policy by all staffs.	□0 ■1 □2	■0 □1 □2	□0 ■1 □2	□0 ■1 □2	□0 ■1 □2	The only method of energy policy awareness/ communication to the employee is via posters in offices and production units.
1.5	Policy available to the public.	Availability of CO_2/energy policy to the public.	■0 □1 □2	■0 □1 □2	□0 ■1 □2	□0 ■1 □2	■0 □1 □2	Some of the industries do not have their energy policy publicly available, however they are provided based on request. Some have it displayed at points accessible to the public within the factory e.g. reception, assembly, notice boars and offices.
1.6	Continuous improvement.	Presence of statement indicating the industry's commitment to continuous improvement of its CO_2 performance in the CO_2/Energy policy.	□0 □1 ■2	■0 □1 □2	■0 □1 □2	■0 □1 □2	□0 □1 ■2	Some of the industries include statement to indicate their commitment to improve their energy efficiency performance in their environmental management system objectives while others did not.
2	**CO_2 TARGETS AND MANAGEMENT PROGRAMME**							
2.1	Time bound CO_2 emissions target.	Presence of a time bound emission reduction target which is clearly define and measurable.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	None of the industries has a clear, measurable and time bound target for CO_2 emission reduction.
2.2	Presence of programme meant for CO_2 emission	Presence of programme specifically meant for	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	None of the assessed industries has a programme in place for CO_2

	management.	management of CO_2 emission.						emission management.
2.3	CO_2 inventory established and regularly updated.	Presence of well established CO_2 inventory that is regularly updated.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	None of the industries keeps an emission inventory of CO_2.
2.4	Responsibilities for achieving targets defined.	Allocation of responsibilities to personnel in order to achieve emission target.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	None of the industries has emission target which will necessitate responsibilities allocated to personnel.
2.5	List of activities and time frame for implementation to meet target.	Availability of well defined set of activities for implementation to meet target.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	None of the industries has emission target and therefore no set of activities for implementation to meet target.
2.6	Consideration of CO_2 emission in business plan.	Demonstration of energy use and CO_2 emissions in business planning by the facility and/or business unit	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	□0 ■1 □2	None of the industries could demonstrate that CO_2 emissions are considered in business planning except for the consideration of the amount of energy to be consumed during planning and this is even from the pricing and costing perspective.
3	**IMPLEMENTATION AND OPERATION**							
3.1	Operational responsibilities defined and documented.	Appropriate allocation and documentation of operational responsibilities required for achieving the target.	□0 ■1 □2	□0 ■1 □2	□0 ■1 □2	□0 ■1 □2	□0 ■1 □2	None of the industries has a target for emission reduction, therefore there is no definition and documentation of responsibilities in this regards. However, there are facility-level responsibilities for energy use management assigned to department or individual (e.g.., Energy Leader) in some of the industries.
3.2	Sufficient resources allocated to achieve targets.	Presence of sufficient resources for CO_2 emission reduction commitment.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	The assessed industries have no emission target/management programme and therefore no resource is allocated for CO_2 emission reduction commitment.
3.3	Training and awareness raising activities.	Provision of CO_2 awareness training to staffs with additional training for key personnel.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	There is no training awareness meant for CO_2 emission management. However, there is general training awareness on environment, health and safety issues that may affect the work and wellbeing of the employees.
3.4	Document up to date.	Presence up to date records	□0 □1 ■2	□0 □1 ■2	□0 ■1 □2	□0 ■1 □2	□0 □1 ■2	Relevant records like the amount of fuel consumed on a monthly basis are well documented and up to date in all the visited industries. However

		and documents.						this data are of different level of comprehensiveness, some of the facilities keep the records as consumed by the different sources while some just keeps the overall fuel supply records.
3.5	Management reporting.	Availability of facility-level reporting for energy use on a pre-determined frequency to the management.	□0 □1 ■2	□0 □1 ■2	□0 □1 ■2	□0 □1 ■2	□0 □1 ■2	In all the industries visited, the utility, engineering department or industrial services provides report for energy use on different periodic frequencies, some on a quarterly basis while some are annually; general environmental assessments are also conducted and reported.
3.6	Research and Development.	Availability of any voluntary corporate investment in research and development, feasibility studies and/or demonstration of technologies and/or new processes that target energy efficiency and reduced CO_2 emissions.	□0 ■1 □2	□0 ■1 □2	□0 ■1 □2	□0 ■1 □2	□0 □1 ■2	All the industries assessed have adapted their processes to be powered by a cleaner and more efficient natural gas; however this decision is purely from the cost saving perspective. Some of the industries as also invested in new technologies and processes that target energy efficiency e.g. the trigeneration plant (which produces electricity, hot water and chilled water from a single fuel source) of one of the visited facilities.
3.7	Investment in renewable energy project.	Presence of any corporate investments in renewable energy projects and/or energy recovery projects.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	□0 ■1 □2	As for renewable energy project, none of the industries has as an investment but some has investment in energy recovery project e.g. the trigeneration plant
4	**CHECKING AND CORRECTION**							
4.1	Monitoring reports and management evaluation.	Verification of energy use and CO_2 emission reports by internal management and/or external regulatory bodies.	□0 ■1 □2	■0 □1 □2	□0 ■1 □2	□0 ■1 □2	□0 ■1 □2	The energy use reports are being verified by the internal management, however this is from the perspective of cost saving. The industries do not report CO_2 emission that will necessitate internal or external verification.
4.2	Energy use and CO_2 emission management strategy publicly available.	Public availability of corporate energy use and CO_2 emission management strategy.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	The energy use records are not publicly available and are treated as classified records. Also the companies have no strategy put in place for CO_2 emission.
4.3	Corrective actions.	Amendment of actions and practices in order to achieve target whenever necessary.	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	■0 □1 □2	The facilities have no emission target and therefore no actions and practices put in place to achieve it.
4.4	An internal CO_2 / Energy management audit is conducted periodically.	Conduction of periodic internal audit for GHG/energy management system.	□0 ■1 □2	■0 □1 □2	■0 □1 □2	□0 ■1 □2	□0 ■1 □2	Some of the industries practice periodic auditing while some do not.

Source: LCMP GHG best management checklist and Author's field work, (2016)

In the second element of the checklist; presence of GHG targets and management programme, all of the assessed industries had a very poor performance in this element, all of the companies had a score of 0 out of a possible 12 except Industry D that had 1which is still poor. This showed that though these industries have policies regarding their emission/energy management they have no concrete plans that will actualize the objectives of these policies. This further buttresses the carefree/lack of follow up attitude towards environmental or carbon emission issues in the nation as a whole as pinpointed by Edeoja and Edeoja (2015).

The third element of the checklist focuses on the actual implementation of any emission management programme of these industries and the provisions put in place to ensure the successful realization of the programmes. Based on the items in this element, Industry N had a score of 5, Industry G had 5, Industry Q had 6, Industry D had 8 and Industry P had 6 out of a possible 14. Also in this element, the companies have an average to below average performance. The fourth element check for the presence of corrective measures in terms of amendment of necessary actions and practices for the achievement of GHG targets whenever necessary and out of a total of 8 achievable score in this element, Industry N had 2, Industry G had 1, Industry Q had 0, Industry D had 2 and Industry P had 2. The companies also performed poorly in this element.

All in all, from the assessment checklist, Industry N had a total assessment score of 13 out of a possible 46 (28% of maximum score), Industry G had 11 (24% of maximum score), Industry Q had 6 (13% of maximum score), Industry D had 19 (41% of maximum score) and Industry P had 14 (30% of maximum score). This showed that none of the industries are close to the desirable performance of best management practices for CO_2 emission as none of them even scored the average of the maximum score possible according to this checklist. The poor performance of these industries can be traced to the fact that Nigeria is still a non-annex (developing nation) member party of the UNFCCC and as such, she is currently not compelled to reduce her GHG emissions although she had agreed to reduce a determined amount of GHG from her national inventory. This has made the regulations of CO_2 emission not to be strong and decisive in the country and off course the industries relaxed and do not see the management of CO_2 emission in order to protect the climate as an utmost priority.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter includes a summary of what has been investigated the whole research and suggestions that were given on how to tackle the problems that have been identified.

5.2 Summary

This study was aimed at assessing the CO_2 emissions from stationery equipments and its management strategies in the Nigerian manufacturing sector by means of some selected industries at Agbara Industrial Estate, Ogun State. In order to achieve this, a total of five industries were selected for the study: Industry N, Industry G, Industry Q, Industry D and Industry P. The use of documented emission factors and activity data methodology was adopted to estimate the emitted CO_2 between the periods of June 2015-May 2016. The closeness of the companies to CO_2 management best practices was also accessed via the use of the best practice checklist for greenhouse gas management designed by the world wildlife fund for their low carbon manufacturing programme. As regards the estimation of the CO_2 emission of these companies, the stationary equipments that combust any kind of fossil fuel in these industries were identified and their activity data which is basically the amount of the fuel combusted in the equipment/sources were collated from fuel use/consumption records like fuel bills or fuel purchased receipts. These data were then multiplied with the appropriate IPCC's default CO_2 emission factors to obtain the amount of emitted CO_2 during the period. A total of 7,714.65 tones of CO_2 were emitted from the identified sources during the assessed period in Industry N, 45,055.45 tones were emitted in Industry G, 8,200.94 tones in Industry Q, 53,195.54 tones in Industry D and 49,247.78 tones of CO_2 were emitted in Industry P. These figures were compared with the inclusion threshold of some popular and well established carbon management programmes around the world and they are found to be way above the thresholds. Statistical analysis showed that natural gas and natural gas combusting sources are basically responsible for CO_2 emission in these industries and as a result, any CO_2 reduction strategy to be adopted in these industries should be focused on natural gas usage and natural gas combusting sources, this can be achieved via improving their energy efficiency, emission efficiency, material efficiency amongst other options. The industries were also found to be poor in their CO_2 management practices and this is detrimental to the collective effort to mitigate global warming as their emission level are found to be significantly large.

5.3 Conclusion

The following were inferred from the results of the study:

i. Natural and natural gas combusting stationery equipments are basically responsible for the CO_2 emitted in the assessed industries during the study period.

ii. Significant amount of CO_2 was emitted by the industries which will be required to be managed/ reduced by the standard of many carbon management programmes around the world.

iii. The industries practiced a poor CO_2 emission management.

5.4 Recommendations

5.4.1 Recommendations for the assessed industries

i. The industries should reduce their fossil fuel especially natural gas consumption by replacing it with non fossil fuel energy sources like solar energy, wind energy e.t.c. or by applying carbon capture and storage technology. This will provide a significant advantage for CO_2 emissions reduction.

ii. Industries should also look inwards to sector specific processes and identify areas where opportunities to improve fossil fuel consumption can be implemented. Opportunities may include better heat management, reduction in yield loss in materials, recycling e.t.c. this will reduce the CO_2 emissions without causing harm to production.

iii. Industries should develop a CO_2 emission inventory. This will allow tracking of their performance and ensure that their actions do reduce their CO_2 emissions. They will also be able to assess their risks and opportunities, follow their progress, and create a strategy to reduce emissions by measurable amounts.

iv. After developing an inventory, industries should fix an emission reduction target to demonstrate their commitment and intentions to track their progress in carbon emission reduction. They should however, monitor their emissions for a period before setting targets.

v. There is also need for communication about carbon management and the creation of awareness regarding carbon emissions, the effect of the emissions on the environment as it relate to climate change, the stand of the organisation and its objectives regarding carbon management issues. This can be delegated to the relevant department e.g. environmental health and safety department.

5.4.2 Recommendations for environmental regulators

i. Regulatory bodies (Federal and State ministries of environment) should incorporate the management of CO_2 and other GHGs (like Methane, oxides of Nitrogen e.t.c.) from the point of view of their impact on climate change into their descriptions. This will ensure that industries are committed to mitigating the impact of their activities on the climate system.

ii. In doing so, they should develop an emission standards/programme where a cap or a predetermined maximum allowable amount of CO_2 and other GHGs (which will be reduced over time) is allocated to industries in a manner that will not hinder the economic development of the country. This will go a long way in helping the country to actualize its fair share of responsibility in mitigating climate change.

5.4.3 Recommendations for further studies

i. There is need for studies of this type in other industrial area in the country where natural gas is not the major source of fuel for industrial activities. This will help to extend the frontier of knowledge and provide an academic basis for accounting of the emissions due to manufacturing industries activities in the country.

ii. There is need for consideration of the other greenhouse gas emissions (like Methane, oxides of Nitrogen, sulfur hexafluoride e.t.c.) in subsequent studies as this is vital for a proper greenhouse gas emission inventories and the development of emission abatement policies in the industrial sector in Nigeria.

iii. The CO_2 emission from industrial sectors like pulp, paper and paper products, printing and publishing sectoral group, textile, wearing apparel, carpet, leather/leather footwear sectoral group, wood and wood products including furniture sectoral group, should also be investigated because they represent a large source of CO_2 emission.

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Appendices

Some of the stationery emission sources in the assessed industries.

(I) A 2188 KVA Cummings gas generators

(II) The flue stacks of two continuous glass furnaces with a combined maximum batch material pull of 380 tons per day

(II) The interior of a 3.5 MW high pressure gas turbine used in generating electricity in one of the facilities in the study area.

(IV) A tri generation plant, capable of producing electricity, hot water and chilled water from the combustion of a single fuel. The plant contains two dual fired (diesel and gas) turbines with a combined power output of up to 8 MW.

(V) An annealing oven (lehr), for the annealing process in glass production. The oven combust liquefied petroleum gas and natural gas.

(VI) An internal bake oven used for curing the over varnish, ink, and inside coating on aluminum or steel food and beverage cans.

(VII) A dual fired (gas and diesel) industrial steam boilers capable of producing up to 15 tons of steam per hour.

(VIII) A dual fired (gas and diesel) industrial steam boilers capable of producing up to 25 tons of steam per hour.

(IX) A 2000 KVA caterpillar diesel engines

(X) Carbon(iv) Oxide emission factors by Fuel

Fuel		Lower heating Value	CO_2 emission factors for fuel consumption data that have been supplied on different measurement bases					
			Energy basis	**Mass basis**	Fuel density information[1]		**Liquid basis**	**Gas basis**
		TJ/Gg	**kg/TJ**	**kg/tonne**	Of liquids (kg/litre fuel)	Of gases (kg/m^3 of fuel)	**kg/ litre**	**kg/m^3**
Oil products	Crude oil	42.3	73300	3100.59	0.8		2.480472	
	Orimulsion	27.5	77000	2117.5				
	Natural Gas Liquids	44.2	64200	2837.64				
	Motor gasoline	44.3	69300	3069.99	0.74		2.2717926	
	Aviation gasoline	44.3	70000	3101	0.71		2.20171	
	Jet gasoline	44.3	70000	3101	0.71		2.20171	
	Jet kerosene	44.1	71500	3153.15	0.79		2.4909885	
	Other kerosene	43.8	71900	3149.22	0.8		2.519376	
	Shale oil	38.1	73300	2792.73	1		2.79273	
	Gas/Diesel oil	43	74100	3186.3	0.84		2.676492	
	Residual fuel oil	40.4	77400	3126.96	0.94		2.9393424	
	Liquified Petroleum Gases	47.3	63100	2984.63	0.54		1.6117002	
	Ethane	46.4	61600	2858.24		1.3		3.715712
	Naphtha	44.5	73300	3261.85	0.77		2.5116245	
	Bitumen	40.2	80700	3244.14				
	Lubricants	40.2	73300	2946.66	1		2.94666	
	Petroleum coke	32.5	97500	3168.75				
	Refinery feedstocks	43	73300	3151.9				
	Refinery gas	49.5	57600	2851.2				
	Paraffin waxes	40.2	73300	2946.66				
	White Spirit/SBP	40.2	73300	2946.66				
	Other petroleum products	40.2	73300	2946.66				
Coal products	Anthracite	26.7	98300	2624.61				
	Coking coal	28.2	94600	2667.72				

	Other bituminous coal	25.8	94600	2440.68		
	Sub bituminous coal	18.9	96100	1816.29		
	Lignite	11.9	101000	1201.9		
	Oil shale and tar sands	8.9	107000	952.3		
	Brown coal briquettes	20.7	97500	2018.25		
	Patent fuel	20.7	97500	2018.25		
	Coke oven coke	28.2	107000	3017.4		
	Lignite coke	28.2	107000	3017.4		
	Gas coke	28.2	107000	3017.4		
	Coal tar	28	80700	2259.6		
	Gas works gas	38.7	44400	1718.28		
	Coke oven gas	38.7	44400	1718.28		
	Blast furnace gas	2.47	260000	642.2		
	Oxygen steel furnace gas	7.06	182000	1284.92		
Natural gas	Natural gas	48	56100	2692.8	0.7	1.88496
Other wastes	Municipal waste (Non biomass fraction)	10	91700	917		
	Industrial wastes	NA	143000	NA		
	Waste oils	40.2	73300	2946.66		
Biomass	Wood or Wood waste	15.6	112000	1747.2		
	Sulphite lyes (Black liqour)	11.8	95300	1124.54		
	Other primary solid biomass fuels	11.6	100000	1160		
	Charcoal	29.5	112000	3304		
	Biogasoline	27	70800	1911.6		
	Biodiesels	27	70800	1911.6		
	Other liquid biofuels	27.4	79600	2181.04		
	Landfill gas	50.4	54600	2751.84	0.9	2.476656
	Sludge gas	50.4	54600	2751.84		
	Other biogas	50.4	54600	2751.84		
	Municipal wastes (Biomass fraction)	11.6	100000	1160		

Peat	9.76	106000	1034.56

Source: World Resource institute, (2015)

(XI) Sample characteristics of the different emission sources and fuel types in each of the assessed industries.

Industry N

Sample characteristics		
Emission sources	Gas generators	Diesel generators
Skewness (SE)	-0.407(0.637)	1.880(0.637)
Kurtosis (SE)	-0.691(1.232)	2.696(1.232)
Shapiro wilk P value	0.613	0.000367

Industry G

Sample characteristics			
Emission sources	Gas generators	Diesel generators	Steam Boilers
Skewness (SE)	3.146(0.637)	1.938(0.637)	1.484(0.637)
Kurtosis (SE)	10.298(1.232)	3.555(1.232)	1.093(1.232)
Shapiro wilk P value	<0.001	<0.001	0.004
Fuel Types	Natural gas	Diesel	
Skewness (SE)	3.145(0.637)	1.950(0.637)	
Kurtosis (SE)	10.292(1.232)	3.619(1.232)	
Shapiro wilk P value	<0.001	<0.001	

Industry Q

Sample characteristics			
Emission sources	Gas generators	Diesel generators	Steam boilers and Ovens
Skewness (SE)	-0.148(0.637)	2.848(0.637)	-0.025(0.637)
Kurtosis (SE)	-1.073(1.232)	8.244(1.232)	0.668(1.232)
Shapiro wilk P value	0.730	<0.001	0.997
Fuel Types	Natural gas	Diesel	LPG
Skewness (SE)	-0.054(0.637)	2.848(0.637)	1.316(0.637)
Kurtosis (SE)	-0.844(1.232)	8.244(1.232)	1.013(1.232)
Shapiro wilk P value	0.764	<0.001	0.012

Industry D

Sample characteristics			
Emission sources	Tri generation plant	Steam boilers	Diesel generators

Skewness (SE)	3.30(0.637)	0.870(0.637)	1.185(0.637)
Kurtosis (SE)	11.153(1.232)	2.079(1.232)	0.660(1.232)
Shapiro wilk P value	<0.001	0.511	0.022
Fuel Types	Natural gas	AGO	
Skewness (SE)	3.131(0.637)	1.392(0.637)	
Kurtosis (SE)	10.494(1.232)	1.184(1.232)	
Shapiro wilk P value	<0.001	0.007	

Industry P

Sample characteristics						
Emission sources	Furnaces	Lehrs	Gas turbines	Gas generators	Diesel generators	Working ends
Skewness (SE)	-0.027 (0.637)	1.822(0.637)	-0.635(0.637)	-0.343(0.637)	1.525(0.637)	-0.087(0.637)
Kurtosis (SE)	-1.808(1.232)	2.779(1.232)	-1.352(1.232)	-1.837(1.232)	1.202(1.232)	-1.886(1.232)
Shapiro wilk P value	0.127	0.002	0.048	0.025	0.001	0.064
Fuel Types	Natural gas	AGO	LPG			
Skewness (SE)	-0.509(0.637)	1.714(0.637)	1.530(0.637)			
Kurtosis (SE)	-1.205(1.232)	1.868(1.232)	0.952(1.232)			
Shapiro wilk P value	0.222	0.001	<0.001			