Airport Carbon Footprint: A case study for Lanseria Airport

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Declaration

I, Tania Chimhau, declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

Signature of Candidate

17th Day of August 2022

Abstract

Climate change is a worrying occurrence, and the rate at which it is changing has exacerbated land degradation. Due to a shift in the global climate zones, rainfall has increased, inevitably leading to severe floods, rising sea levels, hurricanes, excessive winds, typhoons, and more. Climate change affects human health and impacts the availability of basic human necessities such as food security, energy, and freshwater. This mainly affects poor developing countries' environmental health, economic and social systems. Increases in the concentration of greenhouse gases and global temperature have raised concerns globally and locally.

According to the Intergovernmental Panel on Climate Change, the global transport sector accounts for 21% of the worldwide greenhouse gas (GHG) emissions, while aviation accounts for 2.5%. However, aviation activities are increasingly economically important, despite being one of the fastest-growing greenhouse gas emitters globally. Airport environmental protection has become crucial to the global air transport industry, becoming more environmentally aware and increasing their efforts to reduce their environmental impact.

This dissertation explores the carbon footprint of the activities taking place at Lanseria International Airport (LIA), situated in the Gauteng province in South Africa within the Johannesburg Metropolitan area. The GHG emissions were quantified using an Airport GHG emissions calculation tool. The ACERT airport carbon footprint tool considers all emission sources in and around airports. To comply with the proposed objectives, monthly raw data and source documents for all emission activities at LIA were provided by the environmental management team at the airport.

The airport was responsible for 113 069, 112 575, and 83 503 tCO2e emitted during 2018, 2019 and 2020, respectively. Scope 3 GHG emissions dominated and accounted for a significant portion of the total carbon footprint. This scope category is out of the airport's control. Where the airport has control, the emissions are dominated by electrical consumption, which on average accounts for 95% of the Scope 1 and 2 GHG emissions. In the 2019 financial year, LIA generally performed better than in 2018, as the airport implemented multiple projects, including the retrofitting project, to minimize the energy consumption at the airport. In 2020, the airport had a relatively low carbon footprint, as its activities and operation were affected by the COVID-19 pandemic. The decline in GHG emissions is beneficial as fewer GHG emissions are an advantage in the fight against global climate change. However, the

decline in the transportation of freight and passengers renders this a period of crisis concerning business.

The carbon footprint case study for Lanseria International airport demonstrates that the airport operates sustainably. However, to effectively reduce the carbon footprint, the airport is advised to minimise emissions under their direct control. Scope 2 emissions dominate the direct GHG emissions. Therefore, it is recommended that the airport introduce renewable alternative energy sources to mitigate the grid's electricity usage.

Dedication

This one is for me.

Acknowledgements

I would like to thank Lanseria International Airport for funding this project and trusting me to execute it as a baseline for their future carbon accounting projects. This project was both educational and enjoyable. I would like to thank Mr. Laurence Mohlala and his team for taking the time to collect and make available the data I needed for this project.

To my supervisor, Prof. Herman Potgieter, thank you for your patience, guidance, and valuable advice throughout this study; I value the help you have given me. To my co-supervisors, Prof. Kevin Harding and Dr. Sanja Potgieter-Vermaak, thank you for engaging with me and checking in on me regularly as the project progressed.

Table of Contents

▪

List of Figures

List of Tables

Nomenclature

ACIAirport Council International

CO_2Carbon dioxide

CO_2-eqCO_2 equivalent

EFEmission factor

GHGGreenhouse Gas(es)

ICAOInternational Civil Aviation Organisation

IPCCIntergovernmental Panel on Climate Change

LIA Lanseria International Airport

LTOLanding and take-off cycle

NCVNet calorific value

UNUnited Nations

WMO World Meteorological Organization

Chapter 1: Introduction

1.1 Motivation and Background

Air transportation have contributed to the world's economic growth, fostering innovation in tourism and strengthening trade. It has also, in recent years, allowed many people the pleasure of traveling to different parts of the world due to its relative affordability (ICAO, 2014). Thus, air transportation has become one of the most important modes of transport. This has been illustrated by the eruption of the Icelandic volcano Eyjafjallajökull in 2010, which had a tremendous effect on air travel as planes were grounded, leaving many travellers stranded and several business meetings cancelled (Agona, 2010). Globally, roughly 2% to 3% of the world's population can afford to use this mode of transport per annum (Ciers et al., 2018). Despite only being used by 2 to 3% of the global population, air transportation is the sixth-largest contributor of greenhouse gases globally. From 2013 to 2018, Figure 1.1, carbon dioxide emissions from commercial aviation increased almost 70% faster than United Nations projections (Graver et al., 2018). Recent projections estimate that such emissions are on track to triple by 2050, which means they could account for a quarter of all CO2 emissions (IPCC, 2020).

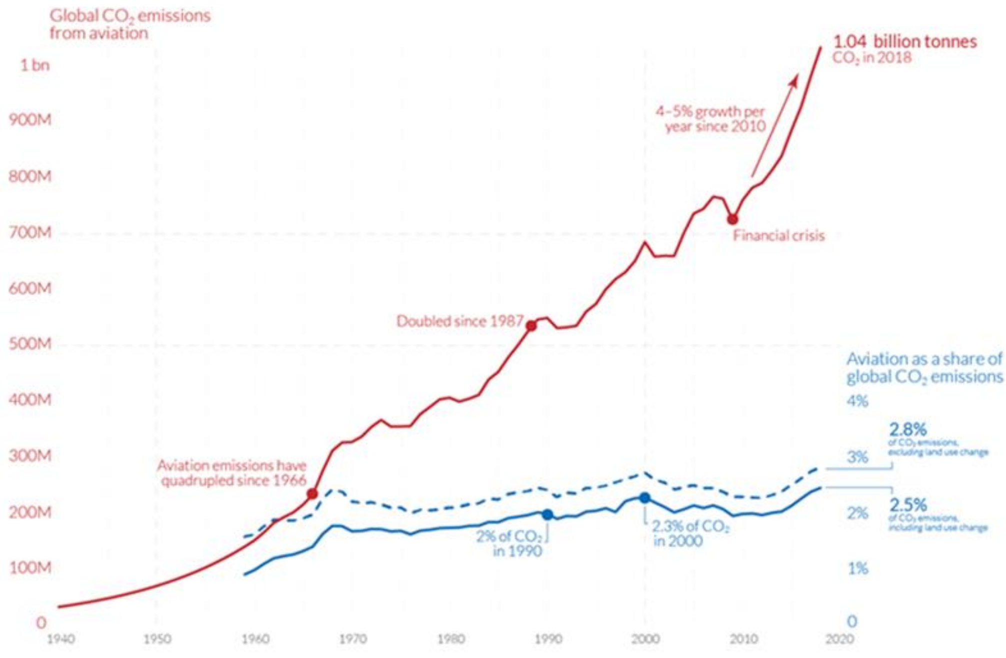

Figure 1.1: Global carbon dioxide emissions from aviation (graph taken from Ritchie, 2017)

Tony Tyler, the CEO of the International Air Transport Associations, stated that 'over the last century, commercial aviation has transformed the world in ways unimaginable in 1914. The first flight provided a shortcut across Tampa Bay. Today the aviation industry re-unites loved ones, connects cultures, expands minds, opens markets, and fosters development. Aviation provides people around the globe with the freedom to make connections that can change their lives and the world. The airport industry, therefore, has a vital role in the global economy. Airports offer various services to passengers and airlines, including facilities and infrastructure for aircraft to land and take off safely, as well as allowing passengers and freight cargo to transfer between the landside and airside of the airport. Furthermore, it houses several tenants offering commercial services to accommodate the needs of the passenger, employees, and visitors. Airport operators also create revenue by selling services and goods to other airports overseas. They house different organisations and companies, including car rental services, air traffic control providers, airlines, ground handling services, and concessionaires. This allows airport operators to perform their roles well in the aviation industry. In 2019, the aviation industry alone had created 63 million jobs whilst having a revenue of 2.7 trillion dollars worldwide, which is 3.5% of the global GDP (International Air Transport Association, 2019).

Addressing the environmental impacts of air travel has become one of the key challenges many organisations face regarding climate change. Environmental protection must consider not only the moral and ethical aspects of an organization but also the commercial implications that may affect growth (Graham & Graham, 2018). Anthropogenic pressures on the environment are changing rapidly, creating multiple observable effects from the temperature, air quality, and weather patterns, as well as diseases and food security issues (Chersich et al., 2018; Ziervogel et al., 2014). Because of this, many countries have implemented domestic carbon pricing initiatives, such as the Carbon Tax Law, to curb the impact of greenhouse gas emissions.

Carbon tax-based laws highlight the cost of greenhouse gas emissions and ultimately provide penalties to those who continue to release carbon emissions beyond what is necessary This is very important because of the global effect of these emissions on the planet, the air, and most of all the species that occupy this space. South Africa is one of the most carbon-intensive economies in the world and became the first African country to implement a carbon tax in 2019.

The South African Carbon Tax Act was implemented on the 1st of June 2019, when The National Development Plan (NDP) recognized South Africa's National Determined Contributions (NDC) to the Paris Agreement (NDP, 2019). The NDP proposed a carbon tax that would economically and efficiently reduce the country's greenhouse gas emissions (SARS, 2019). The Carbon Bill was passed in the National Assembly on the 19th of February 2019. The

Carbon Tax Act 15 of 2019 outlines allowances that can be accessed to reduce a taxpayer's liability up to December 2022. Since the Act has come into effect, implementing the new regulations involves additional payments to all companies, including airports, who emit more carbon than what is deemed necessary. The Act allows for the taxation of any company that emits beyond the necessary at a rate of R127 per metric tonnes of CO_2-eq emitted, with a yearly increase of the amount of consumer price inflation plus two per cent until 2022 (NDP, 2019). Companies may receive tax-free allowances between 60 and 90 per cent of their emissions, reducing their carbon tax rate to between R6 and R48 per metric tonnes of CO_2-eq. This forces companies to take a second look at the waste they are producing and evaluate whether it is not more profitable and more beneficial to their environmental ethos to cut down on these emissions. The allowances taxpayers can access if they meet the requirements include a basic allowance, a performance allowance of up to 5%, a carbon budget allowance, and an offset allowance of up to 10%.

Emissions from aviation activities are of increasing concern to regulators, the public, and therefore also to aviation companies. From 2013 to 2018, carbon dioxide emissions from commercial aviation increased almost 70% faster than United Nations projections (Graver et al., 2018). Recent projections estimate that such emissions are on track to triple by 2050, which means they could account for a quarter of the CO_2 emissions from all sectors at the time.

The aviation industry's environmental impacts, as shown in Figure 1.2, include loss of land, noise, water pollution, climate change, waste generation, air quality impacts, and air pollution. The testing and operations of various aircraft contribute to aircraft noise, which particularly affects residential areas near airports as they are exposed to engine noise during take-off and landing at different hours of the day and night (Halpern & Graham, 2018). The air quality is mainly affected by airport operations (i.e., high-powered runway lighting, generators, and airport vehicles), access traffic, auxiliary airport services (i.e., laundry services and catering companies), and emission from the aircraft (Graham & Graham, 2018). According to a study by Huxham and Nelson (2019), it is estimated that ambient air pollution is responsible for 4% of deaths in South Africa. Many airport operators started monitoring their carbon emissions as a global initiative to address their environmental impacts responsibly and cost-effectively.

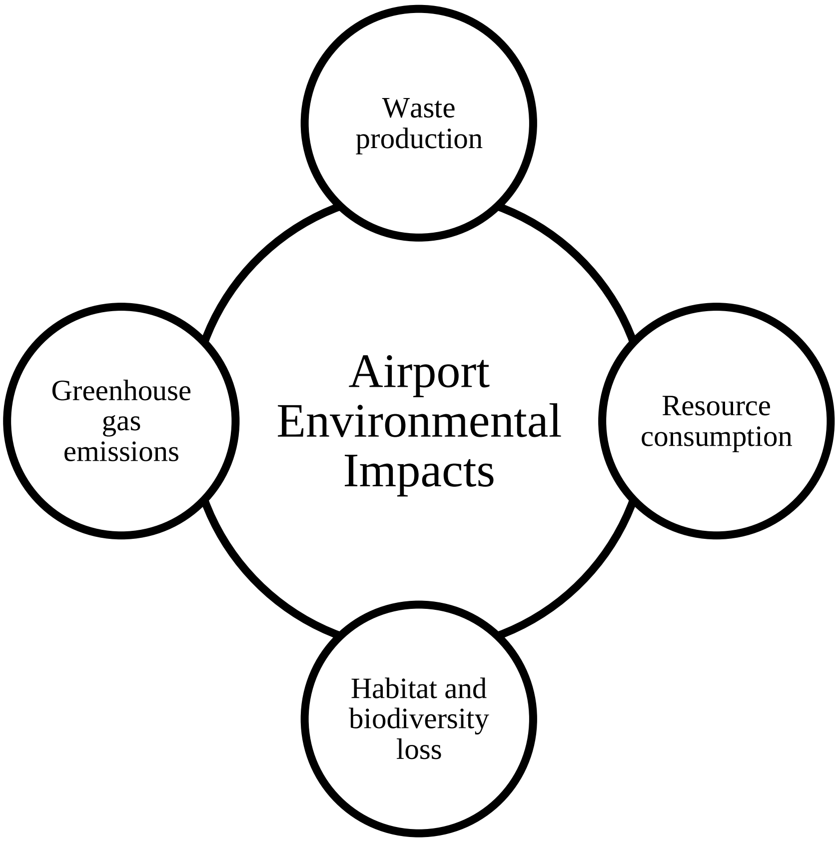

Figure 1.2: Airport Environmental Impacts

Addressing airport operators’ greenhouse gas emissions has become extremely important, as environmental protection is not only an ethical and moral decision, it may also have consequential commercial implications as environmental impact mismanagement may constrain business growth (Budd & Ison, 2017). Airport operation is important in our globalized world, connecting people, businesses, and cargo across different countries (International Air Transport Association, 2019). Therefore, airport operators know that what is good for the environment is good for the business. They are working with organizations such as the Airport Council International (ACI) to address climate change and ensure sustainable development that encompasses environmental, economic, and social sustainability.

Lanseria International Airport (LIA), situated in the Gauteng Province in South Africa within the Johannesburg Metropolitan Municipality area, is a hub for many local and international travellers. Its activities may harm the environment as it houses several charter companies emitting considerable amounts of greenhouse gases into the environment. This research will investigate Lanseria International Airport’s environmental impact and assess the different mitigation strategies that could be implemented to address them. This research also intends to determine what technological and non-technological implementations have been adapted by the airport to manage their greenhouse gas emissions while reducing their carbon tax liability.

1.2 Problem statement

The airport industry is recognized for its indispensable role in the global economy; however, the world's well-being is adversely impacted. This sector is becoming one of the fastest-growing emitters of greenhouse gases and other pollution globally, thus having a significant impact on anthropogenic drivers that influence climate change. The two major concerns that threaten the environment are emissions and noise. The threat is mainly posed by cargo, transfer of baggage, vehicle traffic in and out of the airport, and operations of ground equipment. Furthermore, airports make use of land that contributes explicitly to land, air, and water pollution, consuming excess energy that negatively impacts the carbon footprint. Implementing carbon policies at airports has proven to be difficult on a financial, organisational, and technical level. Achieving carbon emission reduction can be challenging, as an airport's ground support equipment, buildings, air freight handling, and ground vehicles are usually owned by different parties, such as ground access operators, airlines, sub-contractors, government agencies, and stakeholders, and the airport itself.

Energy efficiency has become essential to many industries globally. However, the airport industry has been slow in implementing energy-efficient strategies and waste reduction processes that mitigate the emissions of greenhouse gases. Greenhouse gases such as methane, sulfur oxide, oxides of nitrogen, and carbon dioxide are the main causes of global warming. Emissions of these carbon-rich gases and aerosols at airports have motivated researchers to explore airports' carbon footprint and mitigation strategies. The airport industry has many positive impacts, as it has contributed to the social life of many individuals and businesses, but we should not overlook the negative impacts it has on the environment. Therefore, it is imperative to explore Lanseria International Airport's carbon footprint to understand how its activities affect its sustainability and that of the environment, ecosystem and population. With this information, Lanseria can make informed decisions about the necessary mitigation strategies.

1.3 Research Aims and Objectives

This project will focus on the airport's carbon footprint, wherein the activities, operations, and air pollution monitoring data will be used to calculate the carbon budget. To that end, the following research questions will be asked and answered:

- What categories/operations/activities/actions contribute to Lanseria International Airport's carbon footprint?

- What is the performance of Lanseria International Airport in comparison to other international airports of a similar size?

- What mitigation strategies has the airport implemented to reduce their carbon footprint? What emissions abatement options do LIA have?

The following objectives will underpin the answers to these questions:

- To identify the primary carbon emission sources of the airport
- To identify the sources controlled by the airport.
- To identify which sources third parties control.
- To estimate the carbon footprint for Lanseria International Airport.
- To suggest mitigation strategies.

1.4 Hypothesis

The active implementation of mitigating strategies by Lanseria airport will lead to a decrease in carbon emissions, resulting in a smaller carbon footprint and support a collective drive to meet the goals set out by the global air transportation industry in the pursuit of a deceleration of pollution, for the benefit of the global fight against climate change.

1.5 Dissertation outline

This dissertation consists of the following chapters:

Chapter 1 introduces the motivation and background of the study, the problem statement, and the overall objectives of the case study.

Chapter 2 overviews the climate regime, aviation, and its effect on the environment. It further discusses how carbon accounting benefits the airport operators and carbon emission mitigation strategies

Chapter 3 describes the experimental scope and design used in this study. It also gives a brief background on Lanseria International Airport.

Chapter 4 presents the carbon footprint results from the mathematical model employed and explored the different mitigation strategies that could be implemented to reduce its footprint further. The performance results of Lanseria International Airport were also compared to other International Airports of similar size.

Chapter 5 discusses the impact of COVID-19 on Lanseria International Airport's environmental footprint.

Chapter 6 summarises how the study has met the overall research objectives and specific research questions and also highlights the strengths and limitations of the study. It demonstrates how the results of the study may contribute to better awareness and knowledge in the areas of sustainable transport systems.

Concluding remarks

In this introductory chapter, the motivation and background were discussed. The problem statement, research questions, aims and objectives, and hypothesis were outlined, followed by the dissertation outline, which shows the document's layout.

Chapter 2: Literature Review

2.1 The Climate Change Challenge

Discussions on climate change started in the 20th century when anthropogenically induced climate change arose. The scientific effects were mere assumptions based only on academic knowledge (Gonçalves, 2017). Climate change can be a natural occurrence; however, the rate at which it is currently changing has exacerbated the nature of land degradation, changed the global climate zones, and influenced the increase of rainfall, causing floods, droughts, heat spells, rising sea levels, hurricanes, excessive wind, coastal erosion, typhoons and many more (Balmaseda et al., 2014). It affects not only human health but also the availability of basic human necessities such as food security, energy, and freshwater (Prinn et al., 2005). This mainly affects poor developing countries' environmental health, economic and social systems.

The mean surface air surrounding the earth has increased alarmingly, Figure 2.1, this is mainly caused by the natural and anthropogenic greenhouse gas emissions from agriculture, forestry, and other industrialised lands that have grown over time (IPCC, 2020). Since pre-industrialisation, the global mean surface temperature has risen by 0.87 ℃ while the mean land temperature has increased by an average of 1.53℃ (IPCC, 2020). Studies by the IPCC (Intergovernmental Panel on Climate Change) suggest that the rise of 1℃ above the average mean surface temperature before pre-industrialisation, was contributed by human-induced climate change. It was predicted that the surface temperature would possibly reach a 1.5 ℃ increase between 2030 and 2052 if global warming continued to rise at that rate (IPCC, 2020). Scientists warned that the rate at which climate change is occurring would severely affect the rate at which the earth's surface temperature is rising. They suggested that the carbon emissions should be kept to under 450 parts per million (Yale, 2020). However, in 2016, the hottest year was recorded, even with carbon dioxide emissions of only 400 parts per million (Yale, 2020).

The fight against climate change started in 1979 when the World Meteorological Organization established the First World Climate Change Conference, where scientists gathered to discuss the effect that climate change might have on humankind as the surface temperature continued rising and to prevent potent man-made emissions that could further threaten humanity (Gonçalves, 2017; Iwueke & Alagoa, 2018). This conference led to the establishment of The Intergovernmental Panel on Climate Change (IPCC).

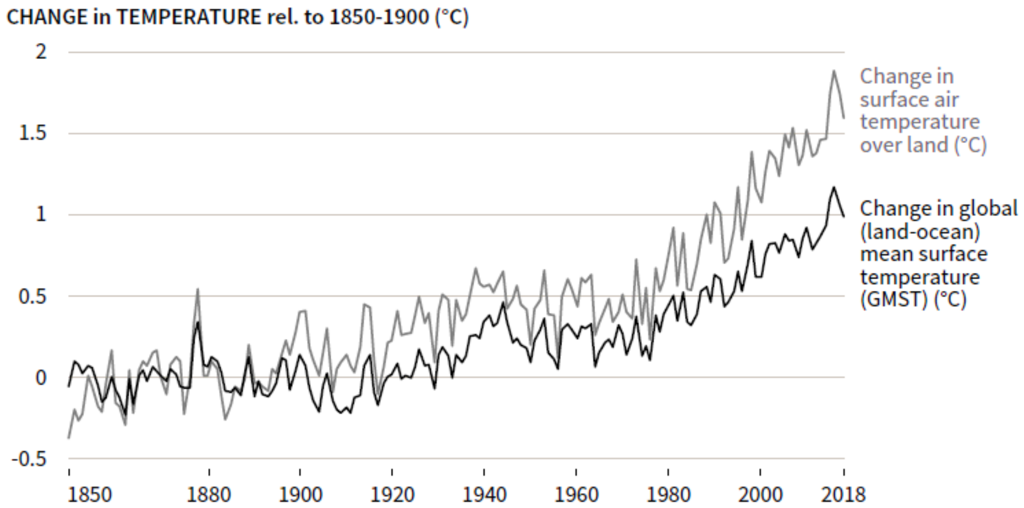

Figure 2.1: Change in temperature of the surface since the pre-industrial period (IPCC, 2020)

2.1.1 Intergovernmental Panel on Climate Change (IPCC)

In 1988, the Intergovernmental Panel on Climate Change was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). Consisting of three Working Groups (WG) (Table 2.1), the IPCC is an assembly of scientists from around the world that gathers data related to the scientific, technical and socio-economic effects of climate change (Balmaseda et al., 2014; Gonçalves, 2017). The data collected is used to assess the effects of human activities on the science of climate change. Each IPCC report released contains 5 to 7 years of literature assessing the changes which occurred during that period while documenting the uncertainties and the mitigation strategies that will be presented to the 195 members (Balmaseda et al., 2014; Roberts, 2020). The IPCC also consists of a Task Force on National Greenhouse Gas Inventories, established in 1996 (United Nations, 2016), continuously developing emission and removal techniques (Roberts, 2020).

Table 2.1: Intergovernmental Panel on Climate Change Working Groups (Roberts, 2020)

Working Group	**Responsibility**

I	Looks at the physical science aspects of climate change and the causes. This includes considering how the climate change system responds to possible change, and this involves the modelling of a process that assesses the performance of climate change when subjected to variations (Roberts, 2020). The model further predicts future changes based on human-influenced climate change.
II	Assesses the impacts of climate change, vulnerability, and adaptation of this change
III	Mitigating and slowing down climate change

2.1.2 The United Nations Framework Convention on Climate Change (1992)

The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental agreement formed in 1992, at the United Nations Convention on Environment and Development held in Rio de Janeiro, Brazil, as a way to fight human-induced climate change (Gonçalves, 2017). This treaty's main objective, according to Article 2, is to:

'*stabilize the concentration of greenhouse gases in the atmosphere at a level that will prevent anthropogenic pressures that interfere with the climate system* (Leggett, 2020)*, given that it is achieved in a time frame that allows ecosystems to adapt naturally to the climate change trends and enables economic sustainability* (Leggett, 2020; United Nations, 2016)'.

It officially came into force on 21st March 1997 (Gonçalves, 2017). The convention consists of 197 parties, who have agreed to, acceded to, or ratified the fight against greenhouse gas-induced climate change (Leggett, 2020). This includes South Africa, which signed the treaty on 15 June 1993 and ratified it on 29 August 1997 (United Nations Framework Convention, 1992).

The convention only focuses on carbon dioxide as it is a greenhouse gas contained in large quantities in the atmosphere (United Nations, 2016). For the Convention of Parties (COP) to achieve their objectives, they are guided by the following principles:

- To preserve the climate system for present and future generations,
- The needs of developing countries within the Parties, especially those that are likely to be affected badly by adverse effects of climate change, should be fully considered,
- Minimize the effects of climate change and in extreme cases evaluate cost-effective mitigation options to maximize the global benefits.
- To promote sustainable development to reduce climate change induced by human activity.
- Create sustainable economic growth by opening international economic systems.

The UNFCCC was created to encourage countries to reduce their greenhouse gas emissions. The Convention does not legally bind them.

2.1.3 Kyoto Protocol

The Kyoto Protocol was adopted in 1997 at a conference held in Kyoto, Japan, at the UNFCCC COP-3. The convention, which consists of Annex 1, agreed to set emission limits for industrialised countries from 1997 to 2012 (Gerden, 2018). However, it only came into force in 2005 and only established the first commitments in the period between 2008 and 2012. The protocol introduced legally binding measures to reduce the emissions of greenhouse gases (Böhringer, 2003; Cirman et al., 2009; Gerden, 2018). In Article 3 of the protocol, all parties are to ensure that their emissions do not exceed the commitments set out in Annex B. It recognises that developed economies are larger emitters than undeveloped industrial economies, thus setting strict measures on developed industrial economies on the principle of the 'common but different responsibilities' (Annex I and non-Annex I) (Gerden, 2018; Gonçalves, 2017). Annex I and non-Annex I must comply with the following:

a) Impose sustainable technologies that minimise emissions.
b) Create national inventories for the different sectors of the economy.
c) Create, implement, publish and update mitigation strategies.
d) Continuously observe the countries' emissions while collaborating with other countries.

The protocol included domestic air travel emissions in the inventories to meet the commitments set out in the Protocol. However, they did not include international air travel emissions(Gonçalves, 2017). This was seen as a problem as imports and exports from other countries do contribute to members' respective emissions.

2.1.4 Paris Agreement

12th of December 2015, at the United Nations Framework Convention for Climate Change COP-21, 196 countries adopted the Paris Agreement (Gonçalves, 2017; United Nations, 2015). It was created to intensify the combat against climate change for both developed and developing countries, accelerating the actions required to minimize carbon emissions for a low carbon future. The Paris Agreement is legally binding for all parties (Streck & Keenlyside, 2016). Figure 2.2 shows the timeline set by the convention to achieve carbon neutrality.

The agreement recognizes that national circumstances are different, hence each member of the convention's main responsibility is to decrease carbon emissions through sustainable development and education. Unlike the Kyoto Protocol, which has a top-down strategy, the Paris Agreement deals with the opposite, i.e., a bottom-up strategy called Intended Nationally Determined Contributions (INDC) (United Nations, 2015). This strategy requires all parties to report on their emissions and how they intend to reduce these emissions. It also does not set limitations and reductions for members of Annex I, but it sets an overall goal in Article 2 to combat climate change(Streck & Keenlyside, 2016).

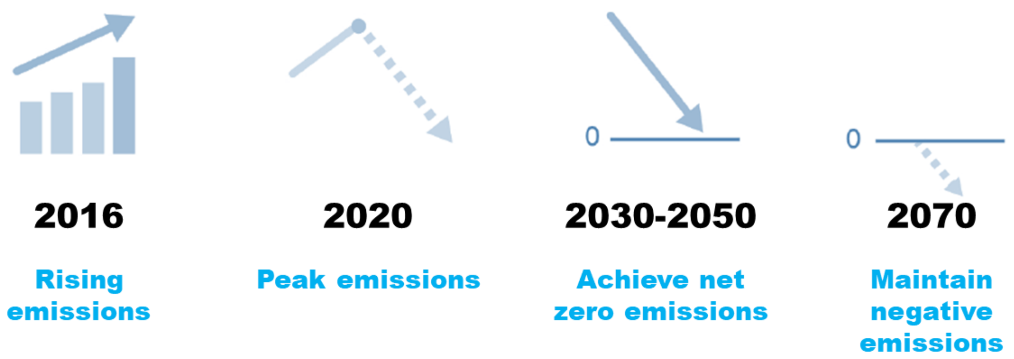

Figure 2.2: Paris Agreement timeline (image adapted from Roe et al., 2017)

Article 2 states that the main aim of the Paris Agreement is to '*strengthen the global response to the anthropogenic carbon emissions by keeping the global temperature below 2*℃ *above pre-industrial levels*'(United Nations, 2015). The Paris agreement put in place the following approach and methodology to be followed by each party of the convention (Wei et al., 2016):

1. It aims for net-zero carbon emissions by the end of the century.
2. Global stocktake to be conducted every five years while strengthening commitments.
3. Effective carbon tax.
4. Accountability for each party.

5. Climate change finance.
6. Ambitious national commitments.
7. Building communities and economies that are unaffected by climate change.
8. Workstream 2 to be used to achieve global commitments before 2020.

The Paris Agreement was seen as a diplomatic triumph after 20 years of climate change negotiations to prevent the disaster of the Copenhagen climate conference that took place in 2009 (Gonçalves, 2017; Streck & Keenlyside, 2016)

2.2 Airports and Global Warming

The global transport sector accounts for 21% of the global greenhouse gas emissions. Aviation, according to "Our World in Data", contributes only 11.6% of the total global transportation greenhouse gas emissions (Hannah Ritchie and Max Roser, 2017). However, aviation activities have received increasing global attention even though it only contributes 2.5% of the total global emissions, which excludes airport operations and construction. This is because as the global population increases, the travel demand also increases. However, not everyone can afford to fly, but those who can cause a large inequality in the emissions. The fact is greenhouse gas emissions due to aviation are increasing rapidly and should be addressed.

2.2.1 Environmental Impacts of Airports

Aircraft noise, air quality, water consumption, waste generation, and the emission of greenhouse gases are some of the environmental effects that occur at airports at a local, regional and global level, with the emissions of greenhouse gases being the most prominent negative effect (Budd & Ison, 2017; Cohen, 2015; Graver et al., 2018). Near airports, the emissions of hydrocarbons, oxides of nitrogen, and carbon dioxide threaten the quality of local, regional, and global air, which poses a risk to human health (Budd & Ison, 2017). Globally, air travel and airports rely on carbon-based fossil fuels for energy. The energy used at airports for storing jet fuel, maintenance, tenants on-site, ground support vehicles, cargo handling, and manufacturing increases the emissions of greenhouse gases exponentially.

The maintenance of ambient temperature in buildings, lighting in the terminal and airfield, and the terminal building air quality consumes a large amount of electrical energy due to the scale of the airfield, airport site, and buildings. Ventilation of buildings is extremely important to minimise the concentration of airborne contaminants and viruses (EPA, 2020; WHO, 2020a). The electrical usage of tenants such as restaurants and souvenir stores requires brighter lighting for special products to appear attractive to the consumer (Budd & Ison, 2017). Additional energy is also required for extra air conditioning as high luminance levels generate more heat due to the lights, thus increasing the energy demand. Airport electrical energy is bought from off-site energy companies, which motivate airport stakeholders financially, to reduce the consumption of electrical energy or to introduce renewable power generation on-site (Budd & Ison, 2017).

Waste generation is a by-product of airport operations. The management of waste at airports is important as the industry continues to grow every day with increasing passenger traffic. Waste management at airports is a critical environmental issue as the activities taking place at a single airport produce waste that is equivalent to waste produced by a community (Baxter et al., 2018; Budd & Ison, 2017). According to the ICAO, airports' operations produce seven different types of waste, including municipal solid waste; construction and demolition debris; waste from aircraft flights (both local and international); international waste; compostable and biodegradable waste; hazardous and industrial waste; and lavatory waste (ICAO, 2017), which has to be processed by disposal to landfill, recycling or incineration. Waste minimization and recycling potentially reduce the emissions of greenhouse gases and alleviates pressure on valuable, scarce resources (Baxter et al., 2018). Several airports have executed sustainable waste management strategies, systems, and policies with the ultimate goal of sending zero waste to landfills. This will reduce their emissions and alleviate pressure on government agencies in charge of waste management (Baxter et al., 2018; ICAO, 2017). LIA has imposed a zero waste to landfill policy. To achieve this goal, LIA introduced worm farming which uses food waste as feedstock to minimise the amount of food material that is sent to the landfill. The worms produce worm tea which is then used as a fertilizer.

Water usage at airports has increased with the substantial growth of the aviation industry, as airports need water to maintain their infrastructure and operations (Baxter et al., 2018; Budd & Ison, 2017). Consequently, large amounts of wastewater are produced. Airport water consumption can be divided into two sections: water consumed by the airports' airside activities via different stakeholders who ensure that everything is running smoothly; and water consumed by activities taking place in the landside area (Carvalho et al., 2013). Landside and airside water consumption includes water for washing, cooking provided by restaurants located in the vicinity of the airport, cleaning, personal hygiene, drinking water for passengers and airport staff, washing aircrafts, and watering plants and the lawn(Baxter et al., 2018). While these are basic requirements, the amount of water consumed at airports can be equivalent to the water consumption of mid-sized cities. This poses a negative effect on a scarce resource and requires airport stakeholders to reduce their water consumption levels. Not only that, but treating large amounts of wastewater requires a significant amount of energy (Baxter et al., 2018; Budd & Ison, 2017; Carvalho et al., 2013). LIA commissioned and developed a 200-million-rand wastewater treatment works in 2012 that complies with and meets the standards of the City of Johannesburg. It recycles 100 per cent of the wastewater produced at the airport and Lanseria Corporate Estate, alleviating the pressures on potable water suppliers (Water and Sanitation Africa, 2011). The airport also has a stormwater harvesting system used for irrigating its gardens. This illustrates the airports' efforts to protect the environment.

Airport environmental protection has become crucial to the global air transport industry. However, the built environment of an airport is not immune to climate change (Baxter et al., 2018; Budd & Ison, 2017). The taxiways, buildings, security systems, runways, ground access systems, and so forth may be affected by the changing climate (Budd & Ison, 2017). Changing weather patterns can severely affect the operations at an airport. Extreme hot weather can damage airfield pavements and aircraft tyres. It also affects aircraft take-off, requiring additional thrust to lift off, burning more fuel. Furthermore, hot weather puts pressure on the energy demand of an airport, as more energy is required to cool down buildings (Budd & Ison, 2017; National Academies of Sciences, Engineering and Medicine, 2016). In cold weather, extreme cases such as increased intensity of storms, flooding, blizzards, and high winds force airports to close temporarily. In 2019, tropical storm Calvinia forced South African Airways to cancel flights between South Africa and Mauritius due to unfavourable weather conditions (Highway Mail, 2019). In the United States, a 2019 level 4 storm in the Bahamas, Hurricane Dorain, caused havoc in the air travel industry as it forced the cancellation of more than 1400 flights forcing several airports in the US to close (Cox, 2019). It is estimated that 70% of airport closures are due to extreme weather patterns and that it is likely to increase in the future (Jankovec, 2017).

2.2.2 Airport operations

Airports emissions usually result from airfreight handling, ground support and maintenance vehicles and energy required to manufacture, store and transport jet fuel (Schare, 2011), Figure 2.3, shows a continuous flow of passengers and aircraft traffic at the airport. Also, operations of the airport tenants (i.e., restaurants, clothing stores and souvenir vendors) and the airport authority contribute to the emission of carbon dioxide (Schare, 2011). Airports need to consider analysing the emissions from the following:

Passenger and employee transportation

Contributors to this section are the transportation of air passengers and aircrew, and visitors and staff travelling to and from the airport on their own, either in private vehicles or using public transport. An additional component is the energy used by the automatic gates used at the entrance terminals due to the opening and closing off for every vehicle that comes into the airport (Wen Lo et al., 2012). It is essential to study the emissions at this point to see what can be implemented to reduce the energy used and thus reduce the effect on climate change.

Pre- and post-departure activities

This includes all the daily operations at the airport, such as airport facilities provided to passengers and visitors, space heating and cooling, waste handling, the use of emergency generators, electricity supply, baggage wrapping services, service providers and other tenants such as car rentals, restaurant facilities, and other activities. This is by no means an exhaustive list, and each of these activities will have an impact on the carbon footprint (Wen Lo et al., 2012), which will be dominated by energy consumption.

Check-in process and security points

This is an energy-intensive operation as it involves the operation of computers and equipment used to print the baggage stickers, as well as conveyor belts used for transferring the luggage. The check-in process identifies emission sources during peak hours and inactive periods. The security point consists of metal detectors and baggage x-ray machines, which may emit harmful greenhouse gases (Wen Lo et al., 2012). These processes are extremely important, and it is worth investigating them.

Flights

The aircraft's emissions are mainly calculated from take-off to landing (LTO). Factors that should be considered to estimate the carbon footprint are ground support equipment used upon arrival and take-off of the aircraft, assisting passengers in disembarking from the airport, mobile generators, air conditioning units to provide the aircraft with heat and cooling when parked, cargo offloading and tractors, hydrant trucks for refuelling, a tug used to tow the aircraft, and airport rescue and firefighting services (Wen Lo et al., 2012).

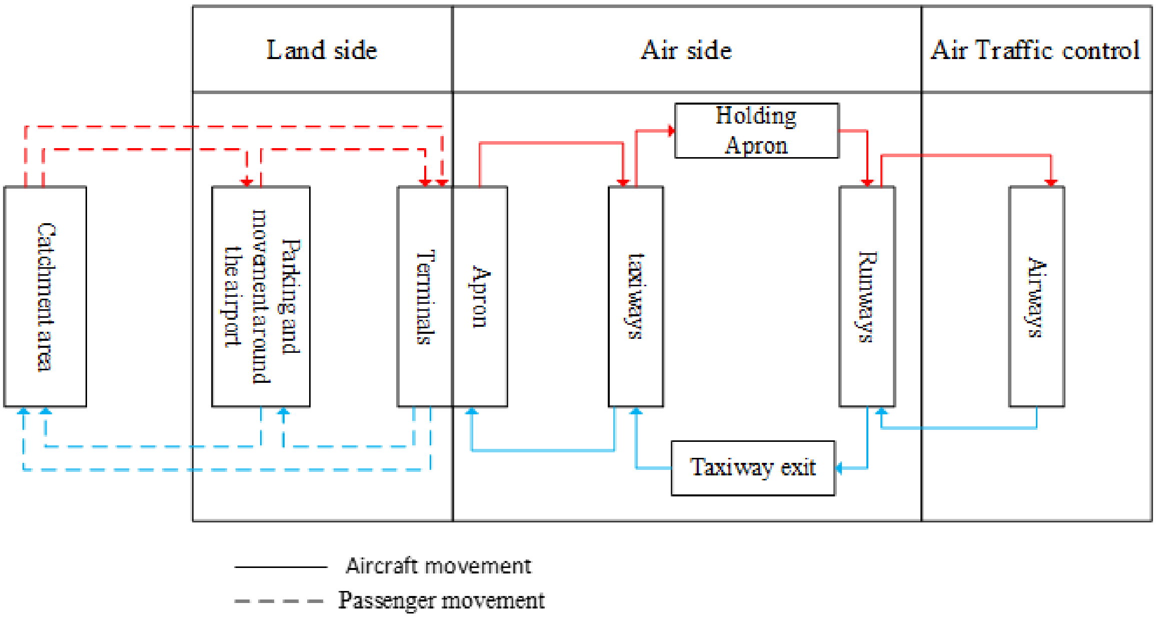

Figure 2.3: Airport aircraft and passenger movement from the land side to the air side and vice versa (diagram adopted from Postorino & Mantecchini (2014)

2.2.3 Greenhouse gases

Increases in the concentration of greenhouse gases and global temperature have raised concerns globally and locally. In Africa, South Africa releases 512.3 million metric tonnes of carbon dioxide annually (Clifford & Mwiti, 2019). Greenhouse gas emissions in South Africa are monitored as it is part of the top 20 countries in the world with the highest emissions. Although the country only releases 1.28 per cent of the global emissions (Ritchie & Roser, 2017; Wwf-Denmark & Troncoso, 2014), it is concerning that the country releases 10 tons per capita which is 3.2 tons per capita above global requirements. The emissions are primarily due to the country's reliance on coal for power. South Africa meets its energy demands by 88% from coal (McSweeney & Timperley, 2018), which emits carbon dioxide in large quantities and poses a threat to humanity. South Africa's emissions per capita are technically equal to the European Union's emissions of 10.9 tonnes per capita and are above that of India and China (Ritchie & Roser, 2017). In Figure 2.4, it can be seen that Europe managed to have fewer emissions per capita compared to South Africa in 2017 (Wwf-Denmark & Troncoso, 2014). This challenges the country to try to minimise its emissions or advocate for more businesses to implement sustainable business solutions as it tries to minimize its reliance on coal.

The consequences associated with human-induced climate change include the rise in the amount of water vapour in the atmosphere, and this leads to destructive storms in different parts of the world. It also causes a rise in sea levels, while high heat waves cause drought in areas where the evaporation is not compensated by increased precipitations (Shahzad, 2017). Increased floods and droughts have a detrimental effect on food production, dislocation of human settlements, ocean acidification, water scarcity, human disease and mortality and severe weather patterns. The deadliest effect of global warming, according to the Intergovernmental Panel on Climate Change, is the rise of sea levels, and this is caused by the temperature rise of the earth, causing the melting of ice and glaciers. This increases the water level of oceans, rivers and lakes (Shahzad, 2017). The rise in ocean levels has led to the disappearance of many small islands, i.e. the Majuro Atoll in the Pacific Marshall Island was projected to lose 80% of land if the temperature continues to rise well above the global community target of 2 °C, thus threatening human livelihoods(Kumar & Himanshu, 2014). Hence, we need to employ low carbon technologies to mitigate these effects.

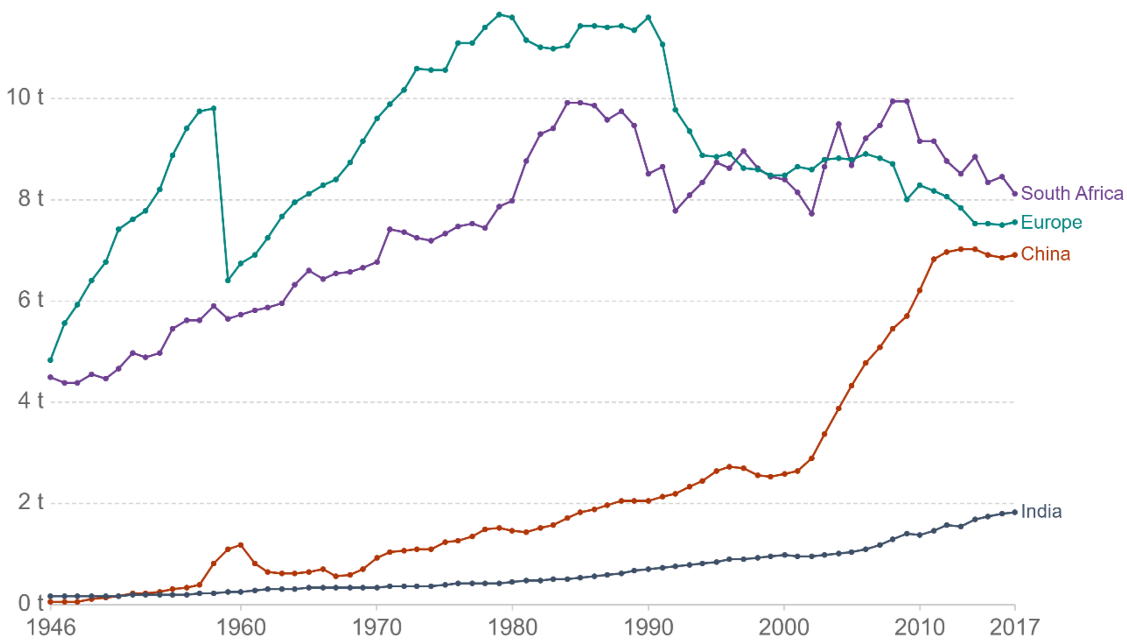

Figure 2.4: Carbon Dioxide emissions per capita for South Africa, Europe China and India from 1946 to 2017 (Ritchie & Roser, 2017)

The emission of greenhouse gases, alongside local air quality and noise which both affect the surrounding areas, is one of the notable adverse effects of airports which does not only affect the surrounding area but has consequences globally (Cohen, 2015). Two-thirds of airports' greenhouse gas emissions come from international flights. However, global aviation is only responsible for 2.5% of greenhouse emissions (Ritchie and Roser, 2017), which if the industry were treated as a nation, it would be the sixth-largest source of greenhouse emissions, with the industry emitting more than Germany (Graver et al., 2018; IATA, 2018).

Table 2.2.2 shows the impact of greenhouse gases (GHG) and aerosols, including carbon dioxide (CO_2), water vapour (H_2O), methane (CH_4), oxides of nitrogen (NO_x) and particulates, have on the airport environment. Carbon dioxide, recognised as the prime potent GHG, forms a cirrus cloud trapping Infra-Red radiation and preventing it from escaping Earth (Chersich et al., 2018; Graham, 2018). Thus, it alters the physical and chemical changes of the atmosphere and leads to global warming, which is the rapid increase in the earth's surface temperature. This begins when the sunlight reaches the surface of the earth, and 30 % of the sunlight is reflected into the atmosphere while the remaining 70% is absorbed and trapped by greenhouse gases, the ocean and the land, resulting in the warming of the earth (Abeydeera et al., 2019). Not all greenhouse gases have the same effect on the atmosphere, and their strength all depends on the average time the gas stays in the atmosphere and the radiative force it causes.

On a molecule-by-molecule basis, it is clear from Table 2.2, that the gases have different greenhouse effects. Ollila (2012) discusses how water vapour accounts for approximately 87 % of the greenhouse gas effect, while carbon dioxide only accounts for 10 % (Ollila, 2012). Although carbon dioxide is responsible for approximately 10% of the greenhouse effect, the rapid emissions of man-made carbon dioxide increase the evaporation rate, affecting the distribution of water vapour in the atmosphere. Because of the rapid increase in human activities, the concentration of carbon dioxide is rapidly increasing, thus affecting the evaporation of water sources. This increases the atmosphere's temperature, amplifying the effect of the other greenhouse gases (Held & Soden, 2000).

Table 2.2: Airport contributions to the chemical and physical changes to the atmosphere

Greenhouse gases & aerosols	**Environmental Impact**
Water Vapour ($\boldsymbol{H_2O}$)	Promotes the formation of contrails and cirrus clouds, which contribute to the warming of the atmosphere.
Carbon Dioxide ($\boldsymbol{CO_2}$)	Largest contribution to global warming by trapping infrared radiation.
Oxides of nitrogen ($\boldsymbol{NO_x}$)	Contribute to the depletion and generation of ozone in the lower and upper troposphere, respectively

Methane (CH_4)	Affects the physical and chemical process of the atmosphere at flight altitude. Powerful infrared absorber.
Particulates (soot and sulphates)	Increase global warming by absorbing radiation, increasing warming (soot); reflect radiation (sulphur particulates) and enhancing cirrus cloud formation.

Figure 2.5 summarises the impacts an airport has on the environment. According to the ICAO, of all aviation activity emissions, 70% is estimated to be CO_2, less than 1 % is oxides of nitrogen and aerosol particulates, and 30 % is methane(ICAO, 2019). For this reason, climate change mitigation is based on carbon dioxide emissions. Several strategies have been put in place by multiple global stakeholders to balance the increasing global air travel demand and the need to reduce global CO_2 emissions. One of the approaches is airport carbon accounting developed by the Airport Carbon Accreditation, which will be discussed in the following section.

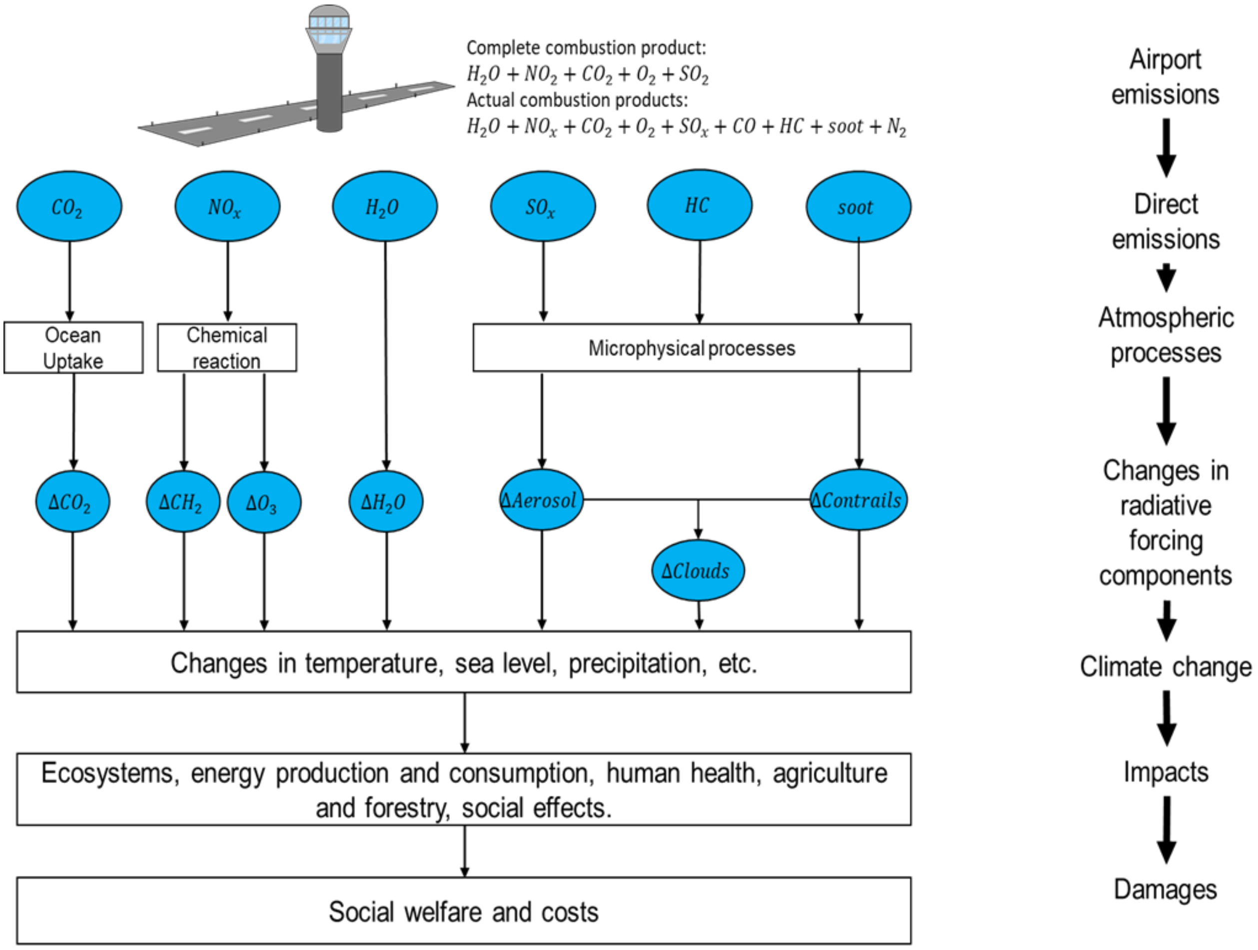

Figure 2.5: Airport emissions and the potential climate and social welfare impacts (adapted from ICAO, 2010)

2.3 Carbon footprint

A carbon footprint was originally defined by Wackemagel and Rees (1996) as an ecological ‘footprint’. The word ecological footprint is expressed as an area which sustains human livelihood in global hectares(Pandey et al., 2011). A carbon footprint quantifies the number of greenhouse gases emitted into the environment from different activities helping various stakeholders manage their emissions and propose technologically sustainable mitigation solutions.

The United Nations states that a carbon footprint combines the indirect and direct greenhouse gas emissions associated with a business’s activities in a product’s or service’s life cycle (Environment, 2018). Carbon accounting provides an overview of the business entities’ greenhouse gas emissions, which are expressed in carbon dioxide equivalents (Asa, 2017). The carbon dioxide equivalents are based on data collected and analysed from internal and/or external sources. This analysis is done to identify reduction methods for energy consumption, and also to reduce the emission of greenhouse gases (Asa, 2017).

Carbon Accounting is a tool designed by the Greenhouse Gas Protocol. It was established by The World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) (Asa, 2017) as an international accounting tool commonly used to manage greenhouse gas emissions. Many business leaders and government officials use the Greenhouse Gas Protocol as a corporate accounting and reporting tool. The GHG protocol accounting tool was created as a method to help quantify the indirect and direct emissions of a business entity’s activities (Schare, 2011).

Many business entities use the Greenhouse Gas Protocol standards and tools to manage their GHG emissions. The Greenhouse Gas Protocol Initiative works with businesses, the government and many environmental groups, globally, to tackle the current global warming challenges the world is facing. The ISO standard 14064-I, Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals, was used as a basis of the protocol in 2006 (Asa, 2017).

Carbon accounting allows an organisation to create an inventory that will register emissions sources as a first step to managing its environmental impact, allowing the organization to track its progress over time (Schare, 2011).

2.3.1 Airport carbon footprint

An organization's carbon footprint helps a business entity quantify its direct and indirect emissions, including company vehicles, energy used in building and even industrial processes. This method does not only quantify the organisation's environmental impact but also provides the entity with an inventory of the greenhouse gas emissions. It will assist the organization in reporting and managing its emissions by setting reduction targets (Awanthi & Navaratne, 2018). In addition, carbon accounting is an effective tool to manage ongoing and future environmental impacts. The greenhouse protocol has designed different industry-specific guidance for every class of organisation.

The Airport Cooperative Research Program (ACRP), with the help of the Greenhouse Gas Protocol, adapted a carbon footprint methodology in 2009 for airports to estimate the carbon emissions (Ekern & Dot, 2009). In 2010, the Airport Council International further adapted an airport operators' manual. This manual states that for airport operators to achieve carbon neutrality they should consider the following steps (ACI, 2010):

1. Motive: Why is the airport operator addressing emissions?
2. Inventory: which pollutants and sources should be included in the carbon footprint and why? How will they be included?
3. Goal setting: What achievements do airport operator aim for?
4. Reduction: how can the operator achieve these goals?
5. Offsetting to achieve Carbon Neutrality: tackling of emissions that cannot be reduced.
6. Reviewing, Reporting and Certification: How to report and gain recognition for achievements.

Based on the manual, Transport Canada created a do-it-yourself greenhouse gas emission tool for airports in 2010, which is called the Airport Carbon and Emissions Reporting tool. This tool was designed for airports with budget constraints to hire private companies to measure their emissions (ACERT, 2017). The tool was developed, with the assistance of the ACI, to measure the CO_2 and secondary emissions from airport activities. It was mainly developed for Canadian Airports, but as of April 2017, it was introduced into the global market for global use. This tool is suitable for Airport Carbon Accreditation (ACA) Level 1 to Level 3+, for all size airports (ACERT, 2017). Apart from ACERT, there are many other calculation methods, such as the ACRP Guidebook (2009), which provides a detailed step-by-step calculation method for the land side and the airside, including the catchment area. It also covers factors for converting non-CO_2 emissions to a metric tonne of CO_2-eq (ACI, 2009). Ideally, a carbon footprint should cover all areas of the airport and activities associated with the airport, such as pilot training. All activities have to be included, otherwise the carbon footprint would lack credibility(ACI, 2009).

In many countries, an airport carbon footprint is not mandatory. However, some airport operators may consider performing a carbon footprint voluntarily to identify, quantify and manage their greenhouse gas emissions. The benefits of performing an airport carbon footprint include:

- Carbon management is good for business strategy
- Energy efficiency
- Social and economic responsibility
- Contributing to the national and global climate change targets
- Improved performance and operational cost efficiency for the airport and its tenants.
- Environmental pressures
- Gaining global recognition

An airport carbon accounting process may appear to be a simple and straightforward process. However, there are many factors to consider in order to produce an adequate carbon footprint report. This includes all three scopes discussed in section 2.3.2.

2.3.2 Types of emissions

The Greenhouse Protocol classifies emissions owned by an organization as sources from direct GHG, Scope 1, or indirect GHG, Scope 2 and 3, emissions. The World Resource Institute (WRI) outlines that the emissions should be reported separately as this allows the airport to identify the ownership and control of emissions (ACI, 2009). Figure 2.6 shows the emission categories for an organization.

The Airport Council International (ACI) describes the direct emissions, Scope 1, as sources owned or controlled by the airport: these may be vehicles owned by the airport, leased assets, boilers and more (ACI, 2009; Cohen, 2015). Scope 2 emissions are described as GHG emissions of the off-site generation of heating and cooling utilities (purchased) and indirect emissions. Scope 3 are sources related to the airport but are not owned or controlled by the airport, such as the employees' travel to and away from the airport (ACI, 2009; Snyder, 2019). Table 2.3 summarizes each category.

Figure 2.6: Emissions from different scopes (Environment, 2018)

Table 2.3: GHGs emissions scope categories at airports

Category	Emissions
Scope 1	This deals with controlled sources, mainly produced within the airport itself. This may include the airport's own power plants that burn fossil fuels, airport vehicles that use diesel fuel or gasoline, and ground support equipment.
Scope 2	These usually only comprise of purchased electricity. It is indirect emissions.
Scope 3	These are indirect emissions that cannot be controlled by the airport; however, they could play a major role in the emissions. This includes passengers and their travel to and from the airport, aircraft emissions, consumer vehicle emissions and waste disposal facilities.

The current methodology recommended by the ACI assesses the emissions based on the different emission scopes. Scope 1 emission sources may include diesel generators, fleet vehicles, power plants and airport-owned GSE either owned or controlled by the airport. Emissions may also include activities performed such as waste disposal and maintenance, repairing and cleaning of the airport (ACI, 2009). The ACI splits Scope 3 emissions into Scope 3a and Scope 3b. Scope 3a are emissions influenced by the airport, while Scope 3b are emissions the airport cannot influence. Scope 3a includes aircraft main engines, aircraft auxiliary power units (APU), landside road traffic/ground access vehicles (GAV), airside traffic and corporate travel ((ACI, 2009). The emissions that the airport cannot influence would include aircraft LTO cycles, rail traffic, waste disposed of off-site and aircraft maintenance. These scopes serve as guidance that allows airports to report GHG emissions if the data is available (ACI, 2009; Ricardo Energy & Environment Ltd, 2018). LIAs scope 2 and 3 emissions are expected to contribute the most to the greenhouse gas emissions as the airport does not have any alternative renewable energy sources and has a very large traffic volume.

Identification of each primary stakeholder responsible for the scopes of airport infrastructure is extremely important to note, and also which stakeholder is best equipped to assist with the mitigation of greenhouse emissions. Table 2.4 shows primary stakeholders and their responsibilities.

Table 2.4: Stakeholders responsible for infrastructure at the airport.

Infrastructure	**Purpose**	**Stakeholder**
Water treatment facilities	Treat water for safe water consumption at the airport.	Airport
Waste management facilities	Management of waste produced at the airport	Airport
Energy generation	Provide energy for the airport	Local Community
Parking facilities	Provide parking space for passengers, visitors, and employees	Airport
Curb	Drop off & pick up zones	Airport
Access road	Transportation of passengers and employees to and from the airport	Airport
Terminal	Processing of passengers from landside to airside	Airport
Apron	Boarding and aircraft maintenance zone	Airline
Gate	Terminal to aircraft zone	Airline
Runway	Provides aircraft with take-off and landing	Aviation regulation services

Taxiway	Movement of aircraft from gate to runway support	Aviation regulation services

2.4 Mitigation Strategies

The by-product of energy consumption arising from both the airside and landside activities is the production of greenhouse gases and airports are urged to implement eco-friendly strategies and policies to mitigate the emissions of these gases (Baxter, 2018). The implementation of innovative energy policies assists airports in reaching their carbon neutrality goals.

With the growing industry, aviation fuel demand will skyrocket in the next decade. The use of kerosene is expected to grow as it is the main component of jet fuel. However, the use of kerosene will increase greenhouse gas emissions. While low-carbon kerosene is slowly being introduced into the aviation industry, it only has a small market share of fuel used in the industry (Bitossi et al., 2020). Albeit airport operations and efficiency improvements can reduce greenhouse gas emissions, sustainable fuels have the potential to mitigate current and future environmental impacts of airports. Hydrogen offers the best fuel alternative. However, modifications to the aircraft body, engine and fuelling infrastructure will need to be employed (Bitossi et al., 2020). The use of renewable drop-in kerosene, including: Hydroprocessed esters and fatty acids synthetic paraffinic kerosene (HEFA-SPK); Hydro processing of fermented sugars synthesised isoparaffins (HFS-SIP); Alcohol-to-jet-SPK (AtJ-SPK); Fischer-Tropsch-SPK (FT-SPK) and Hydrothermal liquefaction, has the potential to decarbonise the aviation industry. HEFA-SPK is the only fuel currently commercialised as it was approved by the Altair Engineering for commercial use in 2011 (Holladay, 2020), and for use in up to 50% volume blends with conventional kerosene (Starck et al., 2016).

Besides sustainable fuel, technological innovations such as modifications to the aircraft body can reduce fuel consumption. Aircraft technology advancement has decreased carbon dioxide emissions significantly over the past few years. Fuel use per kilometre per passenger is now approximately 80 per cent more efficient (ICAO, 2019). Laminar flow control, for wing-based innovation, allows smooth passage of air through the wings and the fuselage. It is estimated that this innovation reduces fuel consumption by 10 % and drag by 20% (Budd & Ison, 2017). However, its implementation outweighs the possible benefits.

Other technological innovations within airports include the use of smart energy control systems which over the years have become popular due to increased 24-hour services, fight operations and comfortable conditions for passengers in terminal buildings, which increase the energy consumption of airports (Akyuz et al., 2019). The smart energy control systems monitor the lighting, heating and cooling of buildings, allow escalators and walkways to only operate when there is high demand, and monitor many other high-energy facilities within the precinct of the airport (Budd & Ison, 2017). The case study at Seve Ballesteros-Santander Airport located in Spain, by Ortega Alba & Manana, shows that the energy consumption of the airport is mainly due to the heating, air conditioning, ventilation and lighting of the terminal buildings (Ortega Alba & Manana, 2017). Lanseria International Airport has sensor-controlled taps inside the bathrooms of the new MSP building to reduce the consumption of water. The lights of the building and the carparks are sensor controlled. Implementing energy monitoring systems reduces carbon dioxide emissions and energy consumption by improving fuel and energy efficiency (Baxter, 2018; Strelkova & Agieieva, 2017).

The carbon footprint of an airport can significantly decrease with the implementation of alternative sustainable power generation to support the existing conventional source of energy. Technological innovations such as photovoltaic (PV) solar panels, cogeneration systems (CHP) and aero generators (wind turbines) are used for on-site power generation (Budd & Ison, 2017; Sukumaran & Sudhakar, 2017). At the Bangkok Suvarnabhumi airport, a study by Somcharoenwattana et al. (2011) analysed the new 52.3 MWe CHP. The plant's operations reduced the airport's primary energy demands by 24 per cent and decreased the airport's carbon emissions by 27%. The case study by Sukumaran & Sudhakar (2017) on the use of a 12 MWp solar PV power generation at Cochin Internation Airport in India, effectively reduced the carbon footprint. Table 2.5 shows the energy-saving implementations at two different airports based on a case study by Baxter et al.(2018).

Table 2.5: Case studies on airports and their sustainability implementations

Airport	**Energy saving implementations**	**Reference**
Copenhagen Airport, Denmark	● Use of LED's ● Groundwater used for cooling and heating ● Solar PV on-site power generation ● Utilization of ground power from parked aircraft.	(Baxter et al, 2018)

	● Sensor controlled escaltors ● Tenant and concessionaire services are montitored with regards to their energy consumption	
Kansai International Airport, Japan	● Usage of LED's ● On-site renewable energy sources (solar and wind) ● Ceiling fans ● Energy monitoring of HVAC ● Usage of low emission ground vehicles	(Baxter et al, 2018)
Darwin Internation Airport, Australia	● Central utility plant 12 ● Onsite solar PV and battery energy storage ● Purchasing renewable energy ● Electrification of ground support equipment ● Fixed electrical ground power ● Sustainable aviation fuel	(CEFC, 2020)

While these technological strategies may be beneficial to airports, many airports are reluctant to employ these changes unless they can be inserted in the existing system or supply chains. Table 2.6 shows a summary of how an airport may mitigate its environmental impact at a local, regional and global level.

Table 2.6: Summary of mitigation strategies (table adapted from Lamb et al., 2020)

Sustainability Indicator	**Mitigation Strategy**
Energy usage and air quality	4 Use renewable energy 5 Manage airport energy consumption 6 Low emission vehicles 7 Monitor air quality 8 Renewable energy sources
Public health	● Monitoring indoor air quality
Water and wastewater	● Water consumption monitoring ● Wastewater treatment

	• Installing water saving devices • Reduction in water pollution
Surroundings	• Reduction of light pollution • Integration of passenger traffic infrastructure • Efficient use of land
Waste management	• Waste management efficiency • Treating hazardous waste from maintenance activities • Recycle waste • Green building efficiency

It is clear that there are many carbon emission sources and contributors at any airport, some under the airport's control and some not, which has to be taken into account when considering compiling the carbon footprint of an organisation. This will require careful consideration when compiling the carbon footprint of Lanseria Airport.

Chapter 3: Method

3.1 Area of study: Lanseria International Airport

Lanseria International Airport (LIA) is a medium-sized airport located northwest of Johannesburg, South Africa, (25° 56' 22.9''S, 27° 55' 32.1''E) and encompasses approximately 324.6 ha of land (Figure 3.1). It is the fourth largest airport (according to passenger numbers) and has been recognized as one of the crucial players in the aviation industry (Geldenhuys, 2016) in South Africa. The airport was officially opened in 1974 and was privately owned. The Airport was sold, on 15 November 2012, to the women's empowerment company Nozala, a consortium consisting of Harith (an infrastructure development fund management company); and the Government Employee Pension Fund (GEPF), through the Public Investment Corporation (PIC) (Moolla & Johnson, 2019).

The airport, Figure 3.2, is surrounded by different businesses, residential areas, and farms such as Kwena Molapo Comprehensive Farm and the Copper Lake Breweries. It is situated 1370 m above sea level (Moolla & Johnson, 2019), experiencing hot summers and cold dry winters. The cold season usually runs from June to July, and this period is typically dry with approximately 0.1% rainfall. Unstable atmospheric conditions are usually experienced during winter and towards the beginning of spring due to the persistent high-pressure systems (Moolla & Johnson, 2019). The warm summer runs from September to February, with rainfall generally occurring from November through March.

LIA cannot be compared to King Shaka International Airport, O.R Tambo International Airport, or Cape Town International Airport, but it is the business hub for many private, corporate and diplomatic aircraft (Geldenhuys, 2016). It is considered to be one of the premiere general aviation airports in South Africa due to its share of the aviation market, superior airside and landside infrastructure, facilities, and service offerings. It has an approximately 3 kilometres long, 45 meter wide runway fixed with advanced and complex radar systems to cater for the lengthy and wide runway (Moolla & Johnson, 2019). Lanseria can be considered one of the busiest domestic airports in South Africa, one of the smallest of nine provinces, but has the largest population (Kriel & Walters, 2016).

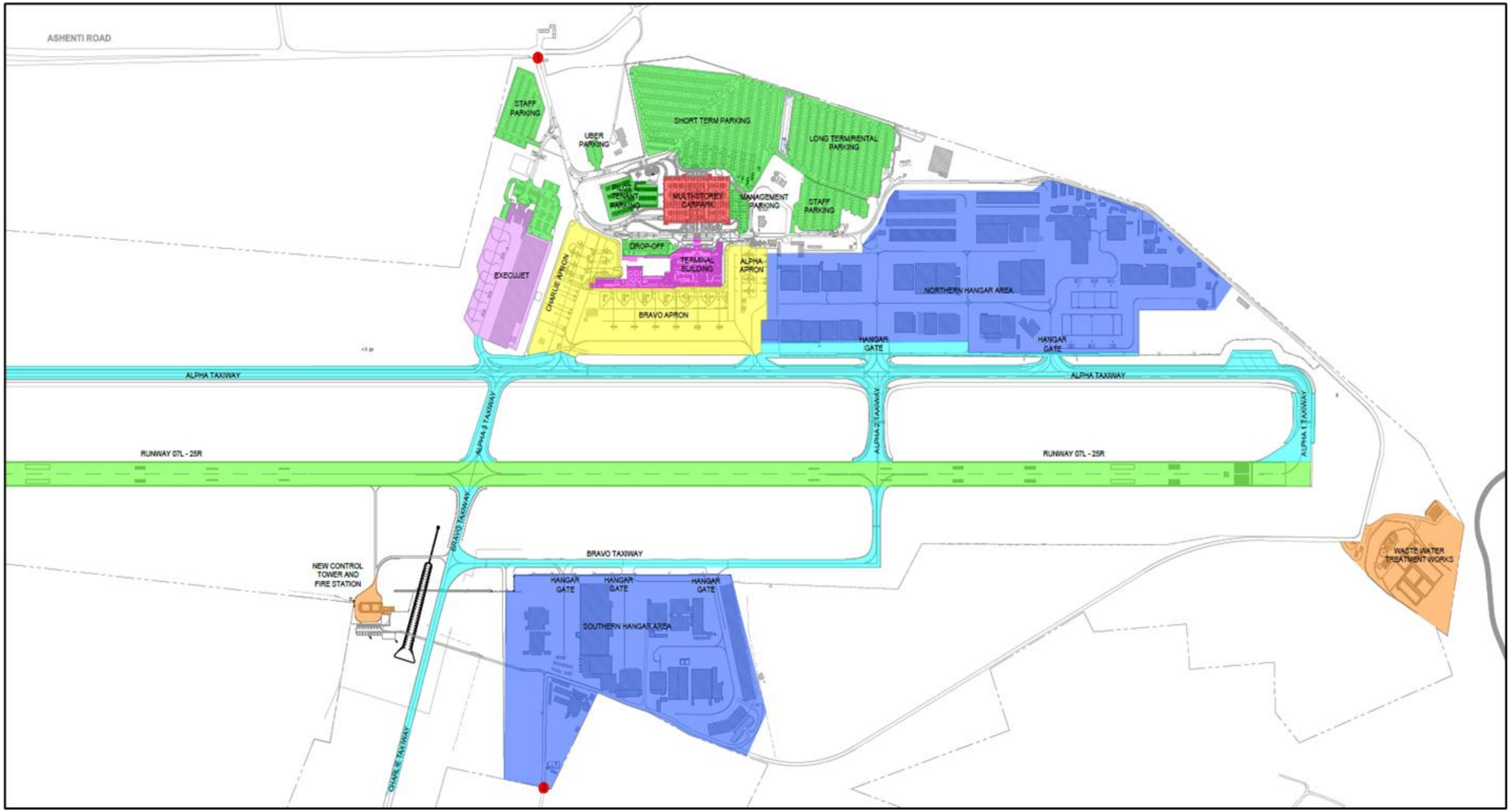

Figure 3.1: Lanseria International Airport layout and general infrastructure

The airport serves various sectors of the aviation market, including charter companies, aircraft sales, aircraft maintenance, pilot training, fixed base operators, freight handling, car hire, duty-free and foreign exchange, emergency and medical services, security services, ground handling, and fuel and air traffic control. Commercial airlines such as Mango, Kulula, and FlySafair flying between Johannesburg and George, Cape Town, and Durban fly every day from LIA. According to a study by Kriel and Walters (2016), the airport is preferred to OR Tambo International Airport due to access time. Most of Lanseria's passengers are those that reside in the central, northern, and western parts of Gauteng. It operated through-out the week with its busiest time during the morning from 06h30 to 09h30 due to local flights from the airport (Moolla & Johnson, 2019).

Figure 3.2: Lanseria International Airport

LIA's facilities and infrastructure are shown in Figure 3.1, and include –

- Airport passenger terminal building and car park building that includes offices and retail facilities.
- Airside aircraft movement infrastructure.
- Airside infrastructure including the control tower and fire station.
- Tenant facilities.
- Landside road and parking infrastructure; and
- Landside infrastructure including bulk water, energy, and sewer infrastructure.

3.2 Method

In this section the procedure used to determine the carbon footprint for LIA is briefly described. The carbon footprinting study was performed using a five-step approach which was developed using standard practices recommended by the GHG Protocol (Figure 3.3) (World Resources Institute, 2012). A detailed description of Scope 1, Scope 2, and Scope 3 emissions calculations will be discussed. This assessment was done in line with the ISO 14064 and ISO 14065 series of standards. It was also done by making use of the following –

- The GHG Protocol Corporate Accounting and Reporting Standard.
- The GHG Protocol Corporate Value Chain (Scope 3) Standard;
- The National Greenhouse Gas (GHG) Emissions Reporting Regulations;
- The Technical Guidelines for Monitoring, Reporting and Verification of GHG Emissions by Industry (Technical Guidelines); and
- The Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines.

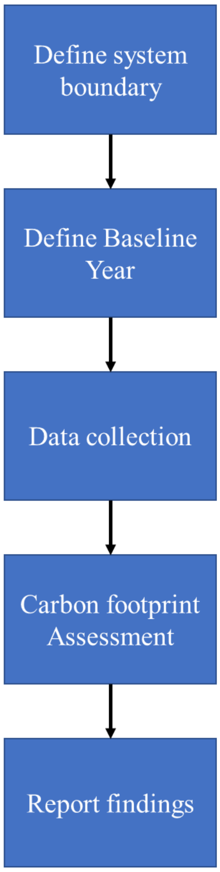

Figure 3.3: Five-step procedure to determine carbon footprint for LIA

3.2.1 System boundary

LIA is an inter-organization consisting of complex organisational and legal structures with varying degrees of ownership and control. However, the implications of GHG emissions affect the entire business entity. Therefore, the first step was to establish an organisational boundary that is sufficiently wide to capture all the GHG emissions of the different business operations within the Airport. The Greenhouse Protocol Standard states that there are two different approaches business entities should adopt to consolidate their GHG emissions (Eskom, 2020) –

1. Operation control approach – GHG emissions from business activities are 100% accounted for by the business entity that has control over the activities taking place.
2. Equity share approach - GHG emissions from a certain activity are accounted for according to the share of equity in the operation conducting the activity

To accurately perform LIA's carbon footprint, it was decided to use the operational control approach. This helps the airport account for all its emissions. All emissions sources within the system boundary should be reported to ensure accurate reporting. The system boundary of LIA (Figure 3.1) was drawn around the whole facility which accurately reflects LIA's emissions. The approach was inclusive of both direct and indirect emissions from all activities at LIA.

3.2.2 Baseline year

2019 financial year was chosen as the base year for the carbon footprint to which all following years can be used by LIA to compare its GHG emissions. In this study, the base year was compared to the 2018 and 2020 financial years.

3.2.3 Data collection

To facilitate meeting the objective of this dissertation, a systematic approach to data collection was vital to accurately account for energy consumption and environmental emissions from each activity. Table 3.1 lists the categorised activity data around the airport boundary that was used to determine LIA's carbon footprint. Data for the inventory analysis came from two sources: primary data collection and secondary data collection. This involved contacting all relevant personnel within the organisation to find what data was available and at what granularity. Monthly data and source documents for all emission activities at LIA were provided by the environmental management team at the airport. Secondary data was utilized to obtain published emission factors to quantify energy consumption and emissions for carbon dioxide, methane, and oxides of nitrogen

Table 3.1: LIA activity data around the operational boundary

	Emission sources
Scope 1 (Direct GHG emissions)	Fuel used for vehicles, including airside transport, machinery, and ground service equipment.
	Fuel used for fire training.
	CO_2 extinguisher used for training or fire-fighting systems.
	Fuel used for stationary emergency power generation units.
	Wastewater treatment
	Waste Management
Scope 2 (Indirect GHG Emissions)	Purchased electricity
	Business travel of airport staff

Scope 3 (Indirect GHG Emissions)	Flights/LTO (landing and take-off) cycle
	Employee transport/private cars
	Construction activities
	Re-sold water to tenants
	Waste generated by third parties
	Cargo activities/Export activities
	Employee transport/bus
	Re-sold electricity

3.2.4 Emission factors

To accurately determine and monitor GHG emissions it is important to use an appropriate method and conversion factors (including emission factors and net calorific values). There are currently three possible methods that can be used to calculate GHG emissions, namely Tier 1, 2, or 3 Methods. As outlined in the IPCC Guidelines (Darío Gómez et al., 2009). Tier 1 involves high-level emission factors and calorific values to be applied to the airport's activity data. Tier 2 and 3 decrease the level of uncertainty and reports accurate GHG emissions inventory. However, the complexity increases with increasing tier.

LIA's carbon footprint has been calculated using emission factors and net calorific values from the Guidelines for National GHG Inventories from the IPCC for each emission category (IPCC, 2020). Where appropriate, country-specific emission factors and values have been applied from the National Greenhouse Gas Emission Reporting Regulations (NGER) (DEA, 2019).

3.2.5 Carbon Footprint Assessment

The quantification of GHG emissions was done using an Airport GHG emissions calculation tool. The GHG Protocol states that these tools are suitable for entities for individuals to assess their greenhouse gas emissions (Acert, 2017; World Resources Institute, 2012). For this carbon footprint, ACERT, Airport Carbon and Emissions Reporting Tool, version 5.1 developed by ACI, was used to develop LIA's emissions inventory. The accuracy of the total CO_2 and CO_2e values derived using the ACERT tool are estimated to be within 10% of a more rigorous and detailed GHG Inventory calculation. The tool was configured in line with LIA's specific requirements to calculate its GHG emissions by converting all the activity and consumption data into GHG emissions using calorific values and emission factors. The GHG emissions were quantified using tier 1, 2, and 3 emission factors to the activity data.

Scope 1

For the quantification of scope 1 emissions, the IPCC defines the following equation to determine the emissions from stationary combustion, mobile combustion, and non-mobile combustion (Darío Gómez et al., 2009).

$$E_i = A \times FE_i \tag{3.1}$$

Where

E_i is the emissions of the pollutant

A is the appropriate indicator of the activity related to the amount emitter,

FE_i is the emission factor for the pollutant i

Scope 2

LIA relies on South Africa's National Grid (Eskom Holdings SOC Ltd) for its electricity supply. Eskom is the only licensed distributor of electricity in the country. This entity primarily relies on coal-fired power plants to provide this service. For this reason, greenhouse gas emissions from purchased electricity, where emissions are generated externally but attribute to the energy consumption of the airport, must be calculated using the location-based calculation method. The location-based method refers to the average emission factor that relates to the grid on which an organisation's power consumption is based (Darío Gómez et al., 2009). Table 3.2 shows the electricity grid emission factor for South Africa.

Table 3.2: Electricity grid emission factor (Pearce, 2020)

Country	Emission Factor	Units
South Africa	0.97	kg CO_2e/kWh

Scope 3

Scope 3 emissions include all other indirect activities ranging from up and downstream controlled but related to the activities of the airport, such as flights or emissions generated during the approach, taxi and ground idle (in), taxi and ground idle (out) and take-off and landing, passenger traffic and tenants' energy consumption. These emissions are out of LIA's operational control and therefore they are harder to manage.

3.2.6 Carbon Footprint reporting

The carbon footprint for financial years 2018, 2019, and 2020 were performed, providing relevant and reliable information regarding LIA's GHG emissions. The carbon footprint will be presented comprehensively in the following chapters to align with the GHG protocol reporting standards.

Chapter 4: Lanseria International Airport's (LIA) Carbon Footprint

In this chapter, Lanseria International Airport's carbon footprint results are presented in conjunction with the analysis of the results and the comparison to other airports of similar size.

4.1 Introduction

The airport industry's forecasted growth in passenger volume traffic and aircraft movements, has led to an increase in air quality regulations and increasing public concern (Comendador et al., 2019). Globally, airports have become more concerned about the negative impact their GHG emissions have on the environment and increased their efforts in reducing their emissions by applying environmental management plans to manage and reduce their GHG emissions. Airports emissions usually result from airfreight handling, ground support, maintenance vehicles and energy required to manufacture, store and transport jet fuel, operations of the airport tenants (i.e. restaurants, clothing stores, and souvenir vendors), and the airport authority (Schare, 2011).

Calculating the carbon footprint for Lanseria International Airport will help the airport understand how the activities taking place at the airport impact its global sustainability. This chapter presents the GHG emissions inventory for Lanseria International airport in 2018, 2019 (baseline year), and 2020. It further compares the performance of the airport in 2019 compared to 2018 while mitigation strategies are offered. The rationale was that 2018 was a pre-COVID year with normal traffic volumes and operations, while 2019 was the year when international and most local air traffic came to a standstill due to the worldwide COVID pandemic and its impact, particularly on the travel, tourist, and air travel industries. In the year 2020, some normality returned and activities in and around airports started to increase again. The performance of the airport in the financial year 2019 was finally compared to other international airports of similar size.

4.2 Material and methods

The ACERT airport carbon footprint tool takes into consideration all emission sources in and around airports. To comply with the proposed objectives, monthly raw data and source documents for all the various emission activities at LIA were provided by the environmental management team at the airport. The carbon footprint around the set boundary for Lanseria International Airport included the following emission sources –

Scope 1: Direct emissions

- Fuel used for mobile combustion;
- Fuel used for firefighting training;
- Fuel used for stationary combustion; and
- Wastewater and solid waste management

Scope 2: Indirect emissions

- Purchased electricity

Scope 3: Indirect emissions

- Aircraft LTO cycle;
- Aircraft APU usage and testing;
- 3rd Party mobile and stationary fuel consumption;
- Tenant energy consumption;
- 3rd party waste management;
- Employee commute
- Passenger airport access

Figure 4.1 presents the calculation principle of the carbon footprint. To calculate the emission inventory for Lanseria International Airport, the emission source data was input into the tool along with the country-specific emissions factors, where required. This yielded greenhouse gas emissions results in metric tonnes of carbon dioxide equivalent (tCO_2e).

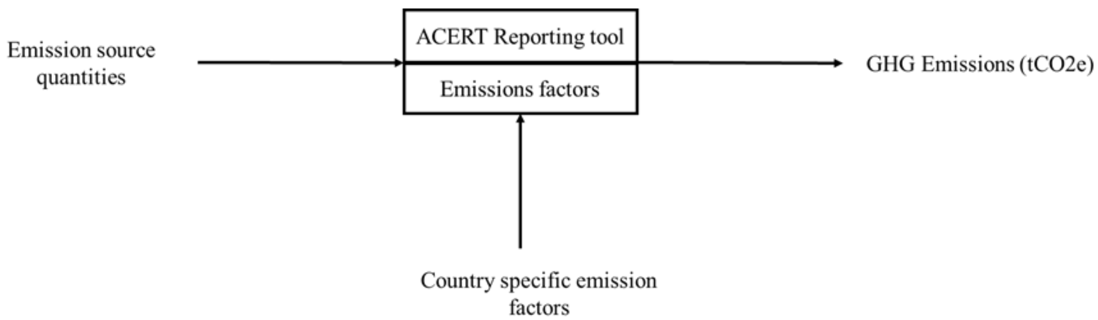

Figure 4.1: Calculation principle of the ACERT carbon footprint tool

The carbon footprint for three different years were explored. The financial year for LIA runs from July 2017 to June 2018, July 2018 to June 2019, and July 2019 to June 2020 for financial years 2018, 2019, and 2020.

4.3 Results and discussion

Lanseria International Airport's carbon footprint covers all three scopes. The GHG emissions for LIA within the set boundary are presented in Table 4.1. The financial year 2019 was defined as the baseline year for this study and was benchmarked against the financial years of 2018 and 2020. The comparison between 2019 and 2020 will be discussed in Chapter 5. Lanseria International Airport has approximately 240 operators on site, therefore the Scope 3 emissions are expected to be higher than the scope 1 & 2 emissions. As illustrated in Table 4.1, Scope 3 emissions dominate the share of the total carbon footprint for all three years. This is followed by the Scope 2 activities. The results from ACERT can be found in Appendix A.

Table 4.1: GHG inventory for the financial years 2018, 2019 and 2020

		2018	2019	2020
	Emission Source	**GHG emissions (tCO2e)**		
Scope 1	Fuel used in mobile combustion	372	218	190
	Fuel used for fire Training	3	1	1
	Fuel used for stationary combustion	50	21	20
	Wastewater treatment and waste Management	160	157	129
Scope 2	Purchased electricity	4 663	4 482	3 897
Scope 3	LTO	83 420	85 437	67 817
	APU	834	855	678
	Vehicles	565	303	289
	Purchased electricity	6 032	5 798	5 798
	Tenant generators	63	27	26
	Fire training	4	2	2
	Waste management	6	11	17
	Tenant and staff vehicles	7 044	5 718	1 205
	Airport employee commuting	1 122	970	832
	Public ground access	8 732	8 575	2 601
Totals	Total scope 1	585	398	341
	Total scope 2	4 663	4 482	3 897
	Total scope 3	107 822	107 696	79 265
	Total emissions	113 096	112 576	83 503
Intensities	kg CO2e/PAX	2,27	2,05	1.77
	kg CO2e/TU	2,26	2,05	1.77

4.3.1 The financial year 2018

In 2018, the airport was responsible for 113 069 tCO_2e emitted into the environment. As illustrated in Figure 4.2, the carbon account is mainly dominated by Scope 3 emissions, which represent a share of 95% of the total footprint. This is followed by Scope 2 and lastly Scope 1, which account for 4% and 1%, respectively.

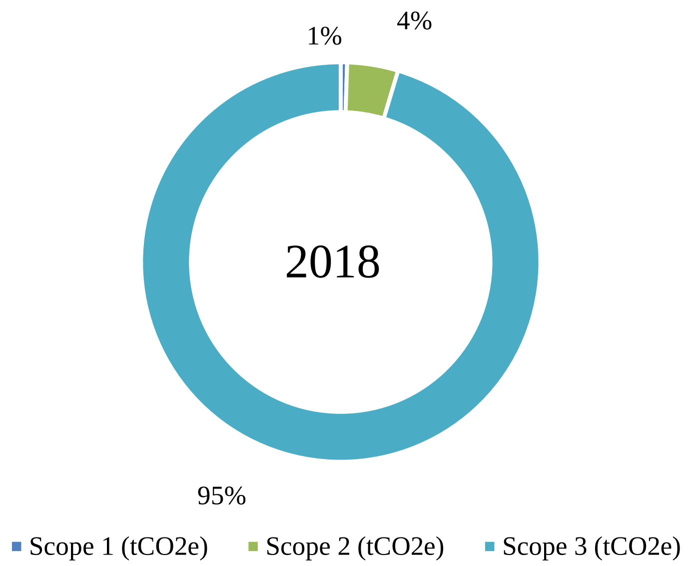

Figure 4.2: Distribution of the 2018 GHG emissions by scope.

The GHG emissions arising from the activities at LIA under the direct control of the airport amounted to 5 247 tCO_2e. Scope 1 emissions only accounted for 11% of the total Scope 1 and 2 emissions. As illustrated in Figure 4.3, fuel used for mobile combustion dominates Scope 1 GHG emissions, with a share of 64%, and accounted for 372 tCO_2e in 2018. The airport vehicle fleet consists of vehicles owned by the airport and the fuel used for these vehicles is provided by the airport's fuel sales system. In this financial year, the airport used 99 588 litres of premium petrol and 43 205 litres of diesel. The second-largest contributor to scope 1 GHG emissions is waste management, which accounted for 160 tCO_2e. The airport recycled a total of 8800 tonnes of waste. The remaining two categories, fuel used for stationary combustion and fire training, account for 8% and 1% respectively. Stationary mobile combustion is mainly due to the diesel used for backup/auxiliary units.

The emissions associated with the use of purchased electricity from the grid dominated the scope 1 and 2 emissions and represent a share of 89% of the footprint. LIA does not use any renewable energy alternatives to supplement the use of energy from fossil fuels.

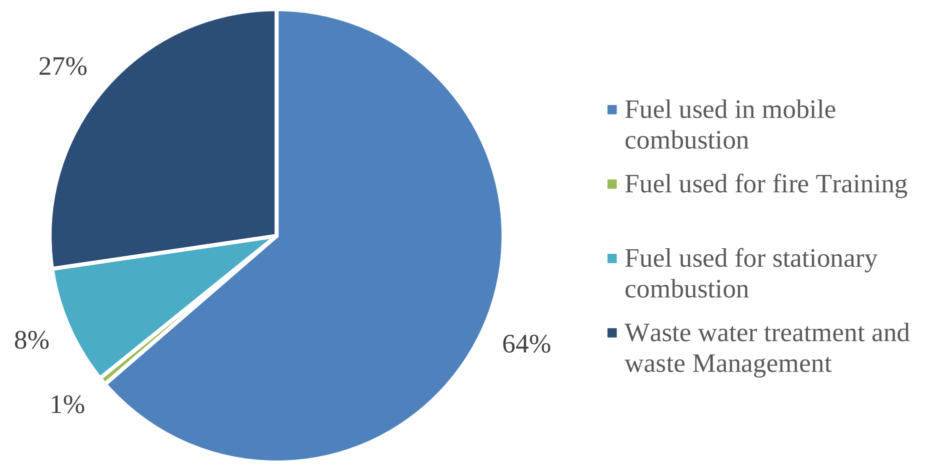

Figure 4.3: Distribution of the 2018 Scope 1 emissions by category.

Figure 4.4, illustrates the emissions associated with the consequences of the use of goods or services provided by LIA. The majority of Scope 3 emissions are mainly from aircraft activities which accounted for 83 420 tCO2e and represent a share of 78% of the total Scope 3 emissions. This is followed by passenger surface access emissions and 3rd party energy consumption emissions which amounted to 8 732 and 6 032 tCO2e respectively.

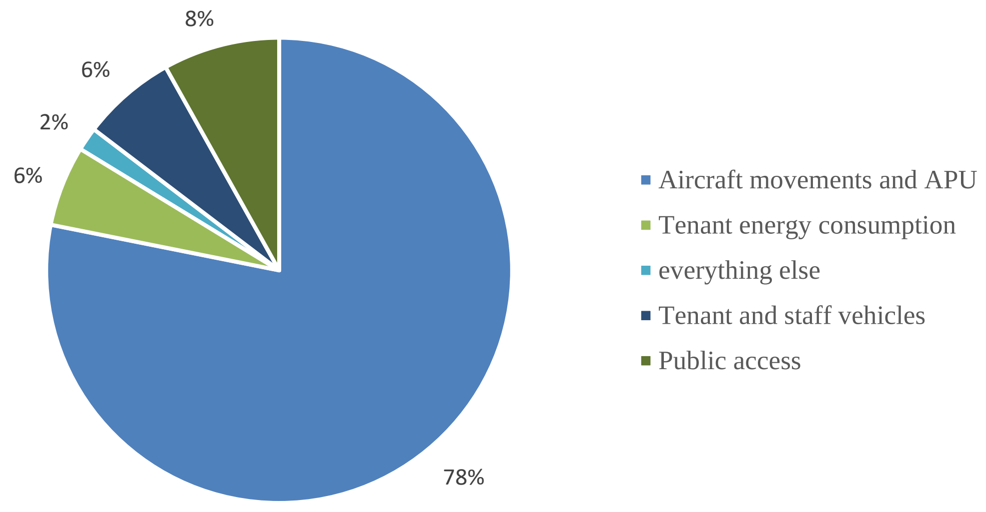

Figure 4.4: Distribution of the 2018 Scope 3 emissions by category.

4.3.2 Financial year 2019

In 2019, the airport was responsible for 112 575 tCO_2e emitted into the environment. The carbon account is mainly dominated by Scope 3 emissions, which represent a share of 95.7% of the total footprint. This is followed by Scope 2 which accounted for 4.0%, together with Scope 1 which accounted for less than 0.5% of the total carbon footprint.

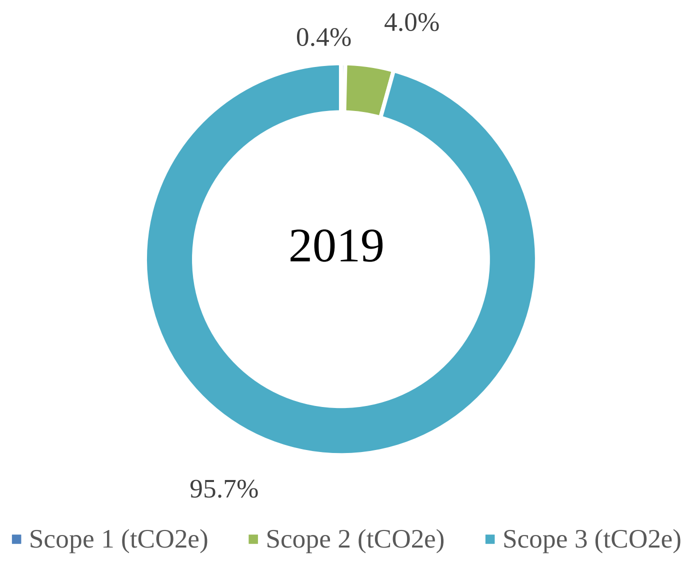

Figure 4.5: Distribution of the 2019 GHG emissions by scope.

In 2019, the total Scope 1 and 2 GHG emissions were calculated to be 4 880 tCO_2e. As illustrated in Figure 4.5, the airport was only directly responsible for 4.4% of the total emissions with purchased electricity dominating the share of scope 1 and 2 emissions. Daily airport operations contribute to a small percentage of the carbon footprint. The direct electrical consumption of the airport accounted for 92% of scope 1 and 2 emissions while daily operation activities only accounted for 8%.

Fuel used for mobile combustion dominates Scope 1 GHG emissions (Figure 4.6) with a share of 55% and accounted for 218 tCO_2e. In 2019 the airport used 43 042 litres of petrol and 42 831 litres of diesel. The second-largest contributor to scope 1 GHG emissions is waste management, which accounts for 157 tCO_2e. In this financial year, the airport recycled 10 117 tonnes of waste. Fuel used for stationary combustion and fire training accounted for 5 % and 3.5 % respectively.

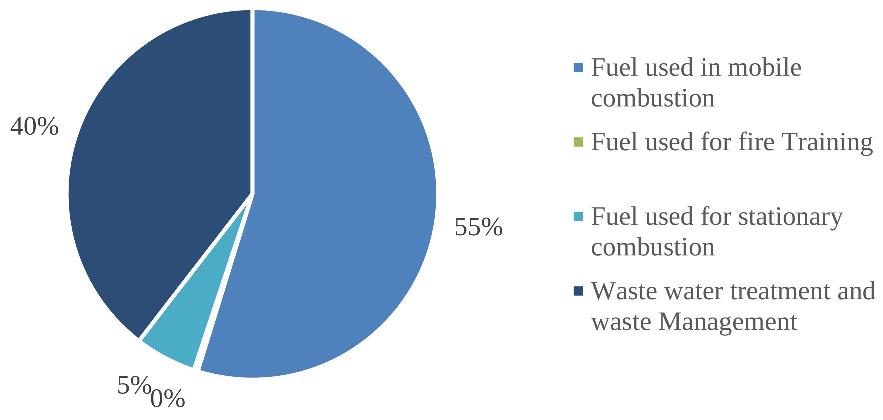

Figure 4.6: Distribution of the 2019 Scope 1 emissions by category.

Figure 4.7, illustrates the emissions associated with the consequences of the use of goods or services provided by LIA. The majority of Scope 3 emissions, Figure 4.4, are mainly from aircraft activities which accounted for 85 437 tCO_2e and represent a share of 80% of the total Scope 3 emissions. This is followed by passenger surface access emissions and 3rd party energy consumption emissions which amounted to 8 575 (8%) and 6 032 (6%) tCO_2e respectively.

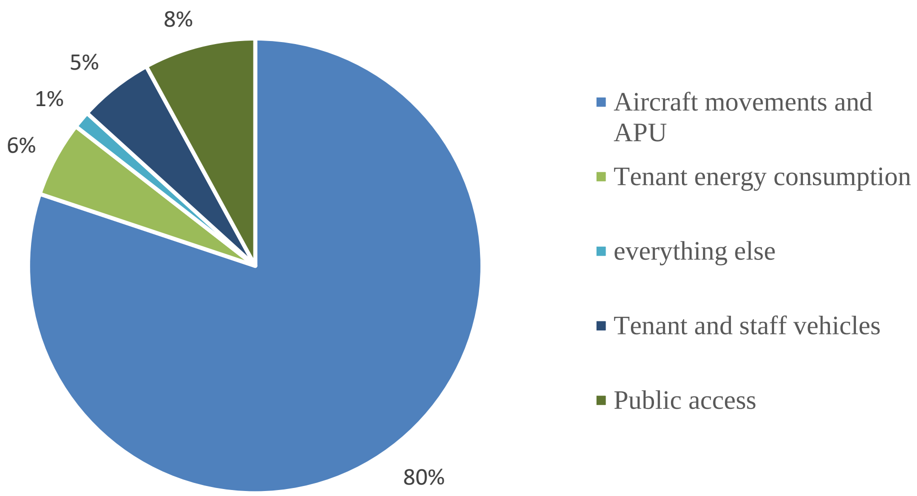

Figure 4.7: Distribution of the 2019 Scope 3 emissions by category.

4.3.3 Comparison of 2018 and 2019

The carbon footprint for Lanseria International airport in 2019 declined by 0.44% since 2018. Table 4.2, all the three Scopes' GHG emissions decreased by 31.98%, 3.87%, and 0.12%

respectively. While the passenger traffic volume and aircraft movements increased in 2019 there was a decline in the total GHG emissions. This is mainly due to a reduction in emission intensities, Table 4.1.

Scope 1

Scope 1 emissions, since 2018, showed the largest decline compared to the other scopes, Table 4.2. This is mainly due to the implementation of energy efficiency projects. The emissions associated with the direct control of the airport, excluding the consumption of electricity, for both years only accounted for approximately 1% of the total carbon footprint.

Table 4.2: Lanseria International Airport's 2018 vs 2019 GHG emissions

Emissions by scope	FY 2018	FY 2019	Percentage change vs 2018
Scope 1 (tCO_2e)	584	398	↓ 31,98%
Scope 2 (tCO_2e)	4 663	4 482	↓ 3,87%
Scope 3 (tCO_2e)	107 822	107 696	↓ 0,12%
Total Emissions t(CO_2e)	**113 069**	**112 576**	**↓ 0,44%**

Mobile combustion

Mobile combustion dominates the scope 1 and 2 emissions for both years. In 2019, the consumption of mobile fuel declined by 40% and the GHG emissions associated with mobile combustion decreased by 41%. This decline is due to the replacement of old engine-driven vehicles and equipment with new and fuel-efficient mobile vehicles. The airport purchased –

- 4 mobile stairs;
- 2 ground power units;
- 3 mules;
- A tug;
- A tractor;
- 2 trucks;
- 1 minibus; and
- 1 light-duty vehicle

By purchasing new engine-driven vehicles and equipment, the airport has significantly reduced the direct consumption of mobile fuel.

Stationary combustion

South Africa has been experiencing load shedding since December 2014, which implies that there is not enough electricity to meet the demands of the country, and rotating power cuts have to be imposed to avoid a total collapse of the energy grid (Nowakowska, 2016). Many industries, including airports, implemented the use of generators/auxiliary power units to supplement these power outages. LIA has eight generators that power the terminal building, runway, fuel depot, control tower, and gate 1. Fuel used for stationary combustion decreased significantly in 2019. In 2018, the airport used 17 784 litres of diesel compared to 2019 when the airport only used 7 648, which is approximately 10 000 litres less than in 2018. Stationary combustion scope emissions decreased significantly by 57% since 2018. Given the total electricity produced by Eskom in 2019 declined by 1.5% since 2018 (Stats SA, 2020). By implementing energy-efficient practices such as the LED-retrofitting project, LIA has managed to reduce the stationary fuel consumption.

Waste management and water treatment

Water supply and treatment are included in the Scope 1 emissions, as the airport is responsible for the supply and treatment of water. The airport treated 128 386 m^3 of wastewater in 2019, which is 12% less than in 2018. This is due to a decrease in consumption as the airport harvests stormwater from the carpark to use for irrigation.

The airport produced 17 255 and 16 586 tonnes of waste in 2018 and 2019, respectively. The total volume of waste sent to the landfill was reduced in 2019 as LIA strives for net-zero waste to landfills. LIA recycled 8 800 and 10 117 tonnes of waste in 2018 and 2019, respectively. There was a 15% increase in the waste recycled by LIA since 2019.

The emissions associated with waste management and water treatment are reported together by ACERT. Waste management and water treatment GHG emissions decreased by 2% from 2018 to 2019.

Scope 2

The emissions associated with the use of purchased electricity from the grid dominated the scope 1 and 2 emissions. LIA does not use any renewable energy alternatives to supplement the use of energy from fossil fuels. To reduce electrical consumption, LIA started a lighting replacement project in 2019, where old conventional incandescent light bulbs were replaced with light-emitting diode (LED) lights. According to the IEA (International Energy Agency), the most cost-effective and simplest measure to reduce electrical consumption is the replacement of traditional lights with highly energy-efficient ones (IEA, 2020). The airport has completely switched from conventional lighting to LED lighting in the terminal building, hangers 10 and 330, gate 18, the wastewater management site, and the main carpark area. The airport's direct electricity consumption declined by 4%, primarily due to the retrofitting project. The overall Scope 2 net emissions decreased by 4% since 2018.

Scope 3

Indirect emissions that cannot be controlled by the airport, are expected to decline the least. This is observed in Table 4.2, as there was only a 0.12% decrease in Scope 3 GHG emissions since 2018. The airport can only guide and influence 3rd party stakeholders to practice environmental conservation through continuous environmental awareness communication such as emails, training, and joint initiatives (Boca Santa et al., 2020).

Aircraft movements

As the passenger volume traffic increases, aircraft movements are expected to rise exponentially. Aircraft movement and engine testing GHG emissions comprise the largest share of carbon footprint for both financial years. In 2019, the aircraft movements increased by 2% as passenger traffic volume increased by 3% since 2018. Although Kulula (one of the operators at LIA) switched from using less carbon-efficient and slightly smaller B737-400 to B737-800 carriers/aircraft, the GHG emissions associated with aircraft LTO movements increased by approximately 2% since 2018.

Passenger ground access

The number of passenger vehicles that accessed the airport in 2018 and 2019 amounted to 960 109 and 857 965, respectively. This was an 11% decrease despite the passenger traffic volume increasing in 2019. This decrease may be due to consumers using public transport to access the airport rather than using their private vehicles.

3rd party energy consumption

The electricity consumption associated with the tenants at the airport decreased in 2019 by 3.7%. Generally, the electricity consumption at the airport had an overall decrease. This is partly due to the retrofitting project that took place in 2019.

4.3.4 Carbon management strategies

GHG emissions are the by-product of energy consumption arising from both airside and land side activities. Airports are urged to implement energy management strategies and policies to mitigate GHG emissions. Lanseria International Airport is working under the Greenhouse Gas Protocol tools and Airport Carbon Accreditation to implement and maintain a carbon reduction plan to reach carbon neutrality goals. LIA implemented a GHG management plan to guide and influence stakeholders to reduce emissions under direct and 3rd party control. In 2019, the airport managed to reduce its carbon footprint, launch a retrofitting project aimed at electrical consumption reductions, replaced old engine-driven vehicles and equipment with fuel-efficient equipment, improved sustainable mobility, and raise awareness regarding environmental practices.

ACI provides airports with a multistep path with the ultimate objective to achieve carbon neutrality. The programme has four steps, namely Mapping, Reduction, Optimisation, and Neutrality. The study aimed to identify the main GHG emissions sources of the airport, the sources under the direct control of the airport, and those that are not under the direct control of the airport.

To effectively reduce the carbon footprint, LIA is urged to maximise the reduction of emissions under their direct control. The Scope 2 emissions dominate the LIA carbon footprint. The carbon footprint of an airport can significantly decrease with the implementation of renewable energy power generation to support the existing conventional power grid. The airport is advised to implement technological innovations such as photovoltaic (PV) solar panels for on-site power generation. The implementation of PV solar panels will not only reduce the scope 2 emissions, but it will reduce the emissions associated with 3rd party electrical consumption. Under Scope 1 emissions, the airport is encouraged to buy bicycles to replace the use of vehicles for certain operations within the vicinity of the airport. This would further reduce the consumption of mobile fuel. Furthermore, it is recommended the airport implements environmental training for old and new staff, students, and stakeholders to drive employee behavioural change.

Where the airport can guide and influence GHG emissions from activities that are not under the direct control of the airport, Scope 3, LIA is encouraged to collaborate with tenants and various stakeholders on the airport site. The emissions associated with the airport's tenant and staff vehicle access contribute significantly to the carbon footprint. It is recommended that the airport encourages the airport staff and tenants to use public transport as opposed to using private cars. The airport is also encouraged to arrange with a public transport corporation between the municipality and the airport to reduce the emissions associated with public vehicle access to the airport. There are initiatives such as the Airport Collaborative Decision Making, whereby the airport and the stakeholders offer clean energy transport solutions to passengers traveling to and from the airport (Comendador et al., 2019). In this case, the airport may partner with Gautrain to reduce the number of vehicles accessing the airport.

4.3.5 Comparison with existing airports of similar size

Financial year 2019 Scope 1 and 2 GHG emissions for Lanseria International Airport were compared to the following airports of similar size -

- **East Midlands Airport** in the UK is an international airport that is part of the Manchester Airports Group (MAG). The airport connects the Midlands to the global economy. Its neighbouring cities are Derby, Leicester, and Nottingham (MAG, 2019). It is at the heart of the East Midlands Gateway (EMEG) which is the central location for rail, cargo, and air travel passengers that support a range of economic activities at the airport (MAG, 2019).

- **Inverness Airport** is a vital airport that serves both national and international travellers in Dalcross, Scotland.

Figure 4.8 shows GHG emissions for LIA, Inverness airport, and East Midlands Airport for the financial year 2019. East Midlands Airport GHG emissions data was reported in the MAG 2019/2020 Greenhouse Gas Emissions Report (MAG, 2020) and Ricardo Energy and Environment reported Inverness Airport's carbon footprint (Ricardo, 2019). East Midlands Airport has the largest Scope 1 and 2 GHG emissions of the three airports, which amounted to 7 503 tCO_2e, while Inverness Airport had the lowest GHG emissions in 2019.

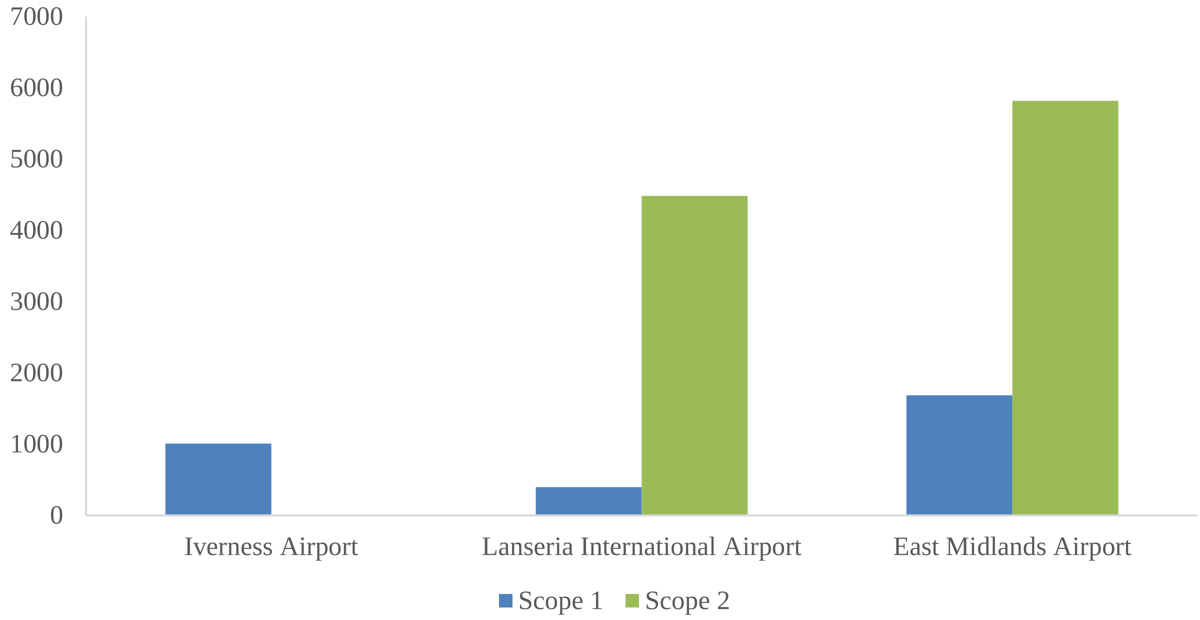

Figure 4.8: Total GHG emissions for the three different airports

In 2019, Lanseria has a passenger traffic volume of 2 376 380, while East Midlands Airport and Inverness Airport had passenger traffic numbers of 5 577 261 and 946 391 respectively. The passenger volume traffic for the three airports are all outliers, therefore it was decided to scale the GHG emissions of East Midlands Airport and Inverness Airport according to the passenger traffic volume of LIA to obtain accurate comparison figures for the three airports. A scale factor of 2.51 and 0.43 was used for East Midlands and Inverness Airport respectively. The Scope 1 and 2 GHG emissions scaled according to the passenger traffic volume of LIA are shown in Figure 4.9.

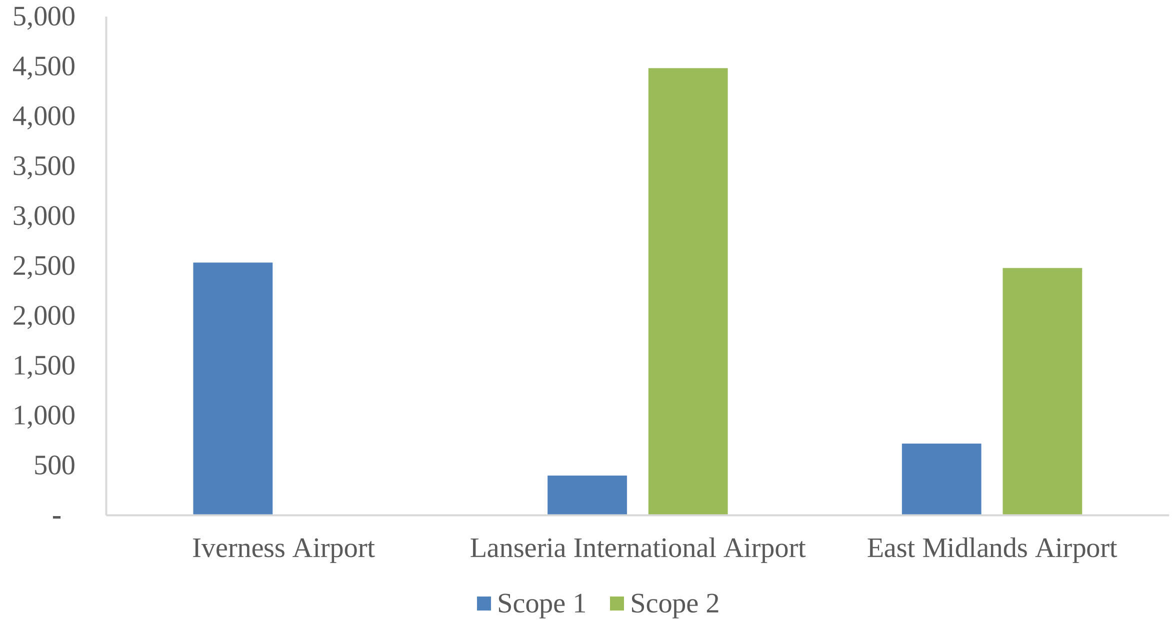

Figure 4.9: Airport greenhouse gas emissions scaled according to Lanseria International airport's passenger numbers.

As shown in Figure 4.9, LIA has the lowest Scope 1 emissions compared to the other two airports. However, LIA has the largest scope 2 emissions. East Midlands has the second-largest scope 2 emissions as it purchases electricity from the grid. It also uses onsite wind-generated electricity to reduce the use of purchased electricity from the grid. Inverness Airport does not have any scope 2 emissions as the airport used 100 % renewable electricity from a third-party supplier. LIA Scope 2 emissions are extremely high, and the airport may need to use an alternative, renewable power source to compete with international airports of similar size.

The Scope 1 GHG emissions of LIA are relatively low as the airport has only four emission sources, including Fuel used for mobile (petrol and diesel) and stationary (diesel) combustion, waste management, and firefighting. Inverness Scope 1 emissions include utilities (gas oil, LPG, diesel, natural gas, refrigerants, and kerosene), fuel used for mobile combustion, and firefighting. East Midlands airport includes fuel used for stationary combustion (natural gas, biomass, LPG, gas oil, petrol, and kerosene) and mobile combustion (diesel, gas oil, and petrol). Inverness has the largest Scope 1 emissions, as the main activities that contribute to the carbon footprint was the stationary fuel combustion and the gas used for terminals for electricity consumption (Ricardo, 2019).

The scaled carbon footprint for Inverness Airport and East Midlands Airport represents an accurate scale to compare the carbon performance of LIA. As disused in section 4.3.4, LIA is encouraged to integrate renewable energy sources for power generation. This will help LIA, reduce their Scope 2 emissions while contributing to a circular economy.

Concluding remarks

LIA was responsible for 113 069, 112 575, and 83 503 tCO_2e for 2018, 2019, and 2020 respectively. Scope 3 GHG emissions dominated and accounted for the major portion of the total carbon footprint which is out of the airport's control. Where the airport has control, the emissions are dominated by electrical consumption, which on average accounts for 95% of the Scope 1 and 2 GHG emissions. In the 2019 financial year, LIA generally performed better than in 2018, as the airport implemented multiple projects, including the retrofitting project, to minimize the energy consumption at the airport. To effectively reduce the GHG emissions associated with its activities, LIA is encouraged to manage and reduce GHG emissions which they have control over. The influence of the COVID-19 pandemic on the carbon footprint for the financial year 2020 will be discussed in Chapter 5.

Chapter 5: The effects of COVID-19 on Lanseria International Airport’s carbon footprint

In this chapter, the effect of the 2019 severe acute respiratory syndrome coronavirus-2 (SARS-CoV) pandemic on Lanseria International Airport’s carbon footprint will be discussed. The carbon footprint results were obtained using the accounting tool discussed in Chapter 4.

5.1 Introduction

The aviation industry, among other vital economic sectors, is extremely vulnerable to external factors. These include terrorist attacks, disease outbreaks, extreme weather patterns, oil crises, and economic recessions (Suau-sanchez et al., 2020). External factors often lead to a severe impact, compared to internal factors. One is faced with increases in flight cancellations, border closures, grounded aircraft, and travel bans, resulting in loss of non-aeronautical revenues for airports (Suau-sanchez et al., 2020). The first disease outbreak to have an adverse effect on air travel was the Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) in May 2003. The SARS-CoV virus had a 10% fatality rate and was later contained in May 2004 (Kandel et al., 2020; Zhu et al., 2020). The International Air Transport Association, IATA, reported that SARS-CoV affected Asia Pacific Airlines Revenue Passenger Kilometres (RPKs) by 35%, which lowered it compared to pre-crisis levels (Pearce, 2020). In December 2019, China reported pneumonia cases to the World Health Organisation (WHO) occurring in Wuhan, Hubei. The virus had aggressively spread throughout China and had a 70 to 80% genetic sequencing resemblance to the SARS-CoV virus of 2003 (Huang et al., 2020). The new novel variant was named 2019 Coronavirus, COVID-19. WHO declared it a public health emergency of international concern on 30 January 2020, and later declared it a pandemic on 11 March 2020 (WHO, 2020b).

The number of cases related to COVID-19 reached a million in April 2020 and surpassed 5.8 million in May (Sun et al., 2020). Following WHO guidelines, many governments imposed drastic restrictions to curb distribution and increase the fight against Coronavirus. These restrictions were based on an observation of China’s experience with the virus (Subramanya & Kermanshachi, 2020). In South Africa, President Cyril Ramaphosa announced a 21-day lockdown on the 26th of March 2020. This lockdown dramatically affected air transport mobility in South Africa. Many countries (see Figure 5.1) closed their borders or imposed strict travel restrictions. This affected the aviation market in South Africa severely, with an impact of 40% (Ni, 2020; Pearce, 2020). Strict travel bans increased the reduction of air passenger demand, resulting in an increase in flight cancelations to prevent the spread of the virus.

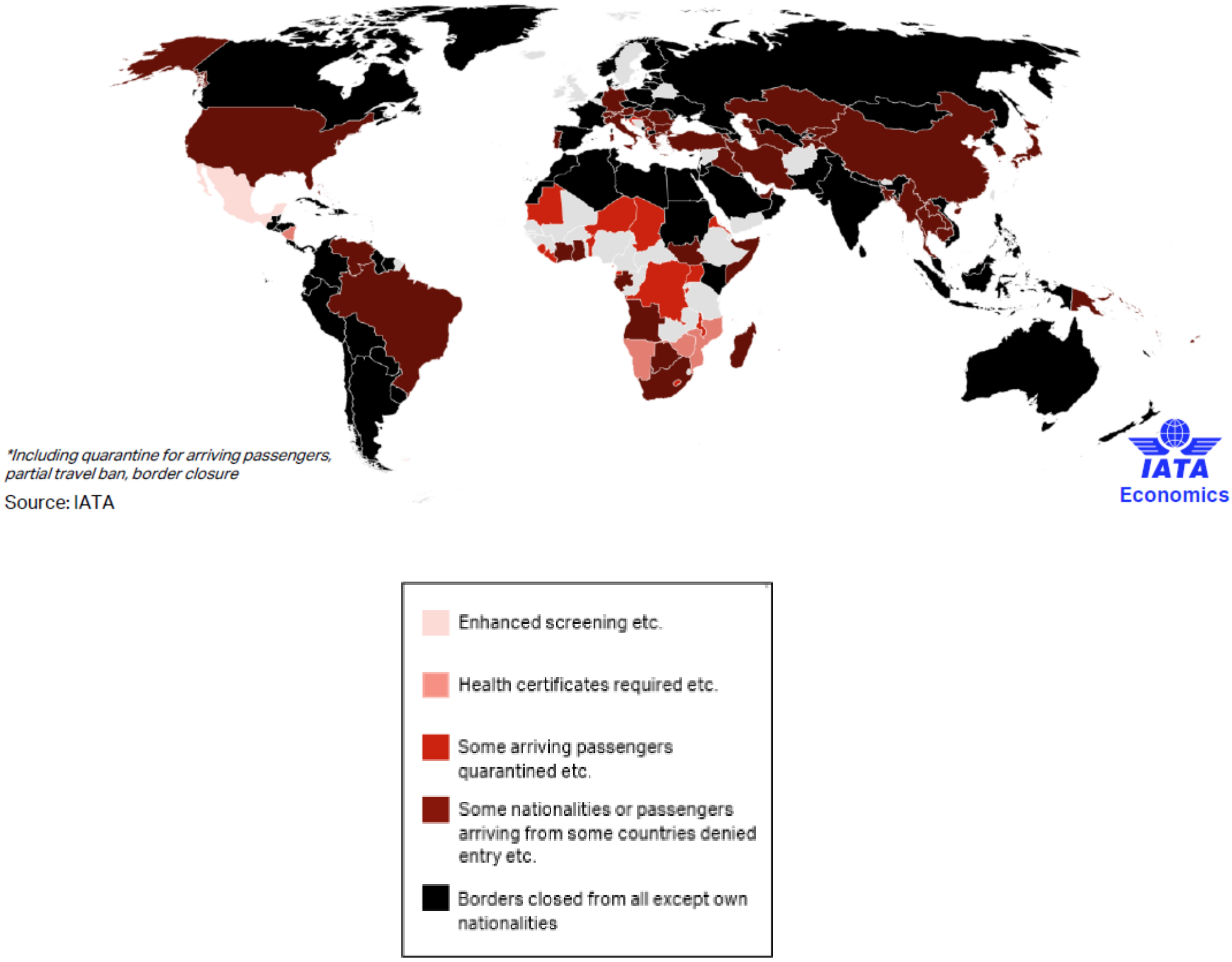

Figure 5.1: Travel restrictions during the COVID-19 outbreak (Pearce, 2020)

Overall, the transport sector was most affected by COVID-19 on an economic level, with both passenger flights and freight transportation suffering severe setbacks. Africa, in 2020, suffered a 32% loss in Revenue Passenger Kilometres (RPKs) (Pearce, 2020) and international arrivals decreased by 44% (Ayiine-etigo & Amankwah-amoah, 2021). With the imposed lockdown restrictions, Lanseria International Airport was forced to stop operations, as aircraft were grounded due to a significant decrease in passenger numbers and to abide with the government's travel restrictions to curb the spread of COVID-19.

Due to grounded aircraft and travel bans, studies have shown that the COVID-19 pandemic led to a decrease in global carbon emissions in 2020 (Statista, 2021). Pre-COVID-19, the aviation sector emitted 915 million metric tonnes of CO_2 globally. In 2020, CO_2 emissions decreased significantly to 495 million metric tonnes (Statista, 2021). The global CO_2 emissions decreased by 54% in 2020, which is a substantial decrease. However, the COVID-19 pandemic only offered a short-term solution to the fight against climate change. In this chapter, Lanseria International Airport's carbon footprint for the financial year 2020 will be compared to 2019 to determine the impact of the COVID-19 pandemic.

5.2 The effect of the novel coronavirus on Lanseria International Airport

In 2020, the carbon footprint within the set boundary is presented in Table 4.2, section 4.3.1. In total, the airport was responsible for 83 503 tCO_2e. The majority of the GHG emissions are caused by Scope 3 emissions which are not under the airport's control. Where the airport has control, most of the emissions are largely contributed by energy consumption.

Total emissions	83 503 tCO_2e
vs 2019	-26%

In 2020, the net emissions decreased by 26%. This decrease is largely due to the impact of the COVID-19 pandemic, leading to local and international travel restrictions, thus resulting in decreased passenger numbers. Overall, the passenger numbers decreased by 21%. In April 2020 the passenger numbers decreased significantly from 134 522 to 45 which was a 99.97% decrease (see Figure 5.2). There is therefore a decrease in the aircraft LTO movements from 4 364 in March 2020 to only 319 in April 2020, which was a 92% decrease. Overall, in the 2020 financial year, the aircraft landing and take-off cycle LTO movements decreased by 21% since the 2019 financial year.

The GHG emissions arising from the activities at LIA under the direct control of the airport accounted for 4 238 tCO_2e of the total carbon footprint and showed an overall decrease of 13% since 2019. This decrease is partly due to the implementation of energy efficient processes in the first half of the 2020 financial year and the travel ban imposed due to the COVID-19 pandemic in the last quarter of the financial year. Electrical consumption of the airport accounts for 92% of the total Scope 1 and 2 emissions, while scope 1 emissions only account for 8%. Net Scope 1 and Scope 2 GHG emissions decreased by 14% and 13%, respectively.

Year	Emission source	Consumption	vs 2019	Total emissions	vs 2019
2020	Mobile combustion	**74 537** litres	-13%	**190** tCO_2e	-13%

The airport vehicle fleet consists of vehicles owned by the airport, and the fuel used for these vehicles is provided by the airport's fuel sales system. Fuel used for mobile combustion dominates Scope 1 GHG emissions, with a share of 56%, and accounts for 190 tCO_2e. In 2020 the airport used 33 837 litres of premium petrol and 40 700 litres of diesel. The mobile combustion total GHG emissions decreased by 13%. This is mainly due to travel restrictions imposed by the government and engine-driven vehicles, including mobile stairs: GPUs; mules, tractors, and minibus were not mobile from March to June 2020.

The second largest contributor to scope 1 GHG emissions is waste management, which accounts for 129 tCO_2e. This is an 18% decrease from 2019. This decrease is partly due to less waste being sent to landfills. Fuel used for stationary combustion accounts for 6 % of the total scope 1 emissions. Stationary, mobile combustion is mainly due to the diesel used for backup/auxiliary units. Fuel used for firefighting training accounts for a very small percentage of the net Scope 1 emissions, i.e., 0.4%. The GHG emissions have stayed the same; therefore, there is no increase or decrease when compared to the financial year 2020.

Year	Emission source	Consumption	vs2019	Total emissions	vs2019
2020	Electricity consumption	**9 994 904** kWh	-6%	**3 897** tCO_2e	-13%

The emissions associated with the use of purchased electricity from the grid dominated the scope 1 and 2 emissions. To reduce electrical consumption, replacing broken lamps with new energy efficient-LED lamps is an ongoing project at LIA. The airport's direct electricity consumption decreased by 6% in 2020, primarily due to the retrofitting project. The overall Scope 2 net emissions decreased by 13%.

Figure 5.2 illustrates the emissions associated with the consequences of using goods or services provided by LIA. These sources include passenger ground access, aircraft movements, APU, 3rd party waste disposal and electrical consumption, and staff travel to the airport. Scope 3 emissions account for 95% of the total GHG emissions, with the carbon footprint of aircraft activity dominating the total emissions. The total aircraft GHG emissions accounted for 79% of the total scope 3 emissions. Another important activity that contributes significantly to LIA's GHG emissions, is the passenger access to the airport, which makes up 6% of the total Scope 3 emissions. The scope 3 GHG emissions decreased by 20% since 2019.

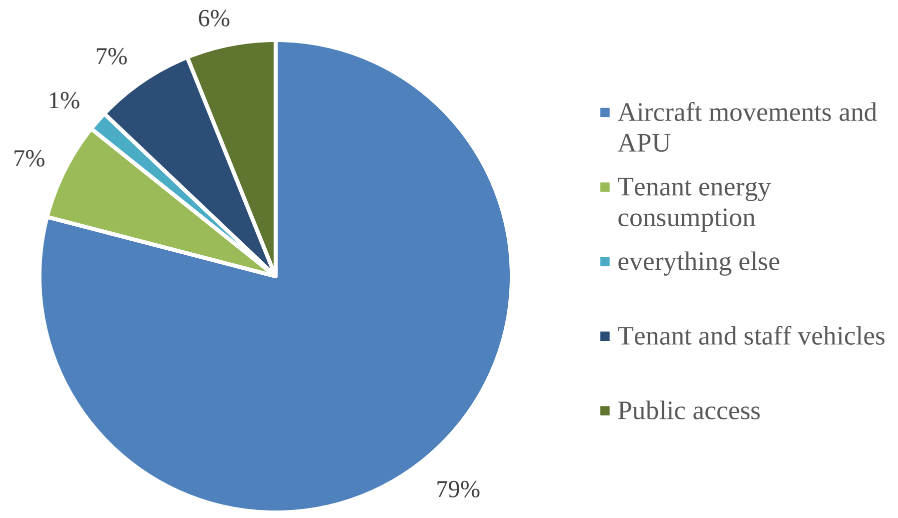

Figure 5.2: Total Scope 3 GHG emissions

When the COVID-19 pandemic hit South Africa in March 2020, there was a reduction of approximately 134 477 passengers in the last quarter of the financial year. As illustrated in Figure 5.3, the passenger traffic volumes declined by more than 95%, showing that April 2020 was a particularly difficult month for LIA. The passenger traffic in 2018 and 2019 followed the same trend. However, in 2020, the passenger numbers generally increased throughout the year as illustrated in Figure 5.3, and the passenger traffic volumes peaked in September and December 2019 with 237 913 and 255 116 travellers, respectively. This demonstrates that pre-COVID-19 passengers were willing to travel. However, due to the spread of the virus, consumer willingness to travel decreased substantially during the disease outbreak.

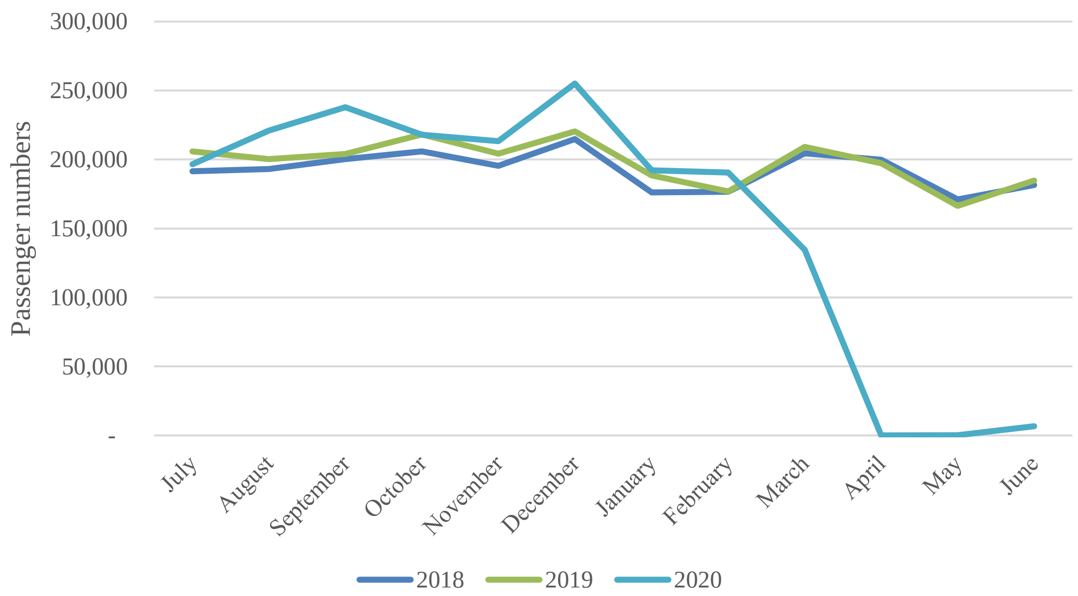

Figure 5.3: Passenger Numbers in different years

The IATA (International Air Transport Association) conducted a study in April 2020 which illustrated that passengers' willingness to travel by air will decrease significantly soon as 30% of the respondents would wait six months or more before considering to travel by air, while another 10% stated that they would wait a year or more after the disease has been contained (IATA, 2019; Lamb et al., 2020a). Figure 5.3 illustrates how passengers' willingness to travel decreased in April. As much as the air traffic started rising again in May 2020 (Figure 5.4), the passenger traffic volume barely increased. In June, there were 2 802 LTO movements, but there were only 5000 passengers who accessed the airport during that month. This shows consumer behaviour, influenced by the COVID-19 pandemic, affected LIA in the last three months of the 2020 financial year. The fear of unemployment, serious illness, transmitting the virus to one's family and friends and the fear of being responsible for another's death, are all real fears that have originated from the reality of living in a pandemic (Lamb et al., 2020b). These factors have shifted the pattern of behaviour in society, as illustrated by the shift in people's willingness to travel by air.

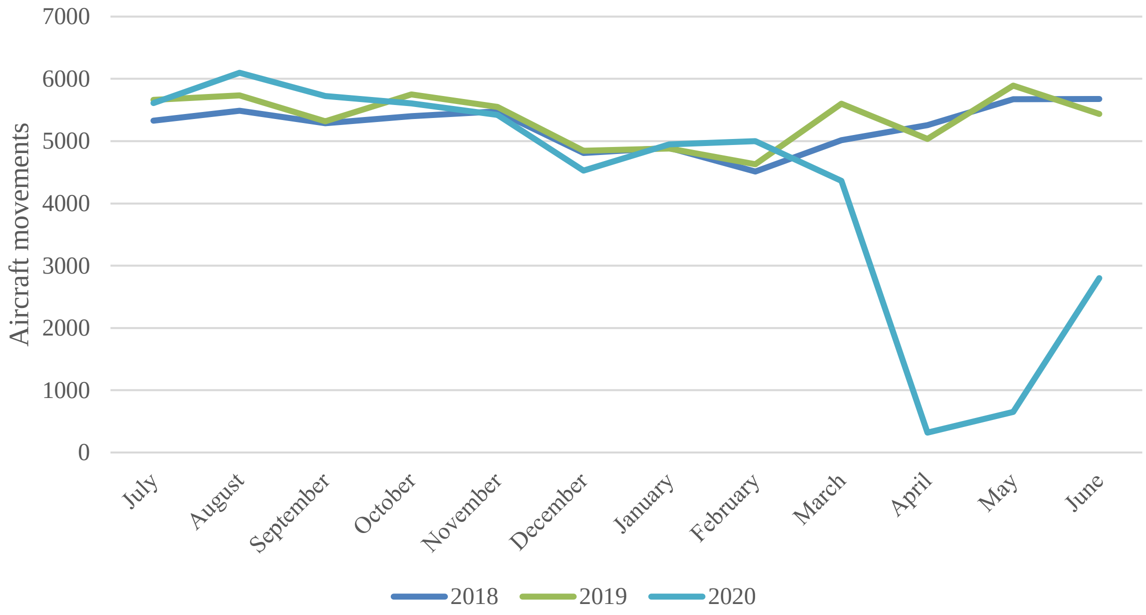

Figure 5.4: Aircraft movements

Air traffic sustains the airport business, and 95% of the airport's revenue is dependent on passenger traffic volumes. As discussed, the sudden drop in passenger traffic volume led to a decline in air traffic and income. This has affected aeronautical and non-aeronautical revenues (Twinn et al., 2020). As many aircraft were grounded in the last quarter of the financial year, airlines had to cut capacity, leading to a decline in aeronautical revenues that LIA receives from the various airlines and charter companies, including security charges and aircraft landing charges which all decreased. Restaurants, parking facilities and duty-free non-aeronautical revenues fell as people stopped flying. According to the ACI, total airport revenues decreased by 35% in the first quarter of 2020 and by 90% in the second quarter (ACI, 2020). The current study does not evaluate the impact of the COVID-19 pandemic on the airport's revenue. Continued studies may evaluate the impact of the virus on the airport's carbon footprint and revenue in 2021 compared to the baseline year, 2019. As advancements in the vaccine rollout have increased, people may be willing to again travel more.

Concluding remarks

In conclusion, Lanseria International Airport's 2020 carbon footprint was indeed affected by the COVID-19 pandemic. The total GHG emissions amounted to 83 503 tCO_2e and decreased significantly by 26 % since 2019. Table 5.1 shows the decline in the individual scopes compared to 2019. This decrease, due to external factors, highlights the impact of global events on even the most stable and consistent of industries. The effect on an industry, such as aviation, is bittersweet because, on the one hand, fewer carbon emissions are an advantage in the fight against global warming and climate change. However, the decline in economic activity due to less transportation of freight and passengers, renders this a period of crisis with regards to employment, tourism, and global trade.

Table 5.1: Decline in GHG emissions by scope

	vs 2019
Scope 1	↓ 14%
Scope 2	↓ 13%
Scope 3	↓ 26%

Chapter 6: Conclusion and Recommendations

6.1 Conclusion

This case study aimed to determine the carbon footprint of the airport, where the data of the activities, operations and air pollution monitoring data was used to calculate the GHG emissions. The findings of the study are listed as followed -

- The carbon footprint for LIA was calculated for 2018, 2019 and 2020. The airport was responsible for 113 069, 112 575 and 83 503 tCO_2e for 2018, 2019 and 2020 respectively. Scope 3 GHG emissions dominated and accounted for the major portion of the total carbon footprint which is out of the airport's control. Where the airport has control, the emissions are dominated by the electrical consumption, which on average accounts for 95% of the Scope 1 and 2 GHG emissions.

- LIA, compared to Inverness and East Midlands airport, has the largest scope 1 and 2 emissions. Although the airport has the lowest scope 1 emissions compared to the other two airports, LIA has the largest scope 2 emissions.

- LIA has implemented a GHG management plan to guide and influence stakeholders to reduce emissions under direct and 3rd party control. In 2019 compared to 2018, the airport managed to reduce its carbon footprint by launching a retrofitting project aimed at electrical consumption reductions, replacing old engine-driven vehicles and equipment with fuel-efficient equipment, improving sustainable mobility and raising awareness regarding environmental practices.

- The 2019 severe acute respiratory syndrome coronavirus-2 (SARS-CoV), COVID-19, impacted significantly on the carbon footprint for LIA. In the last three months of the financial year 2020, when South African President Cyril Ramaphosa announced a 21-day lockdown, the passenger volume traffic dropped significantly due to consumer behaviour influenced by the COVID-19 pandemic. This decrease highlights the impact of global events on even the most stable and consistent of industries.

The finding of the case study suggests that LIA operates sustainably and is actively implementing its GHG management plan.

6.2 Recommendations for future studies

Based on the results of this study, the following recommendations can be made for future studies –

- To effectively reduce the carbon footprint further, LIA is advised to implement renewable energy power generation to support the existing conventional power grid. Implementing technological innovations such as photovoltaic (PV) solar panels for on-site power generation can not only mitigate the emissions associated with Scope 2 but also mitigate the emissions associated with 3rd party electrical consumption.
- Under Scope 1 emissions, it is advised that the airport invests in bicycles to replace the use of vehicles in certain operations within the airport. This will reduce the consumption of mobile fuel.
- Evaluate the impact of the COVID-19 pandemic on the revenue of the airport.
- Perform a study on the carbon footprint of the airport post-COVID-19.

It is recommended that similar studies are done every year to measure the carbon efficiency of the airport using 2019 as the baseline year.

6.3 Contribution of the study

Calculating the carbon footprint for Lanseria International Airport will help the airport understand how the activities taking place at the airport impact their own as well as global sustainability. It will also help LIA identify the categories that contribute most to the carbon footprint, allowing the airport to create a GHG management plan to mitigate those activities.

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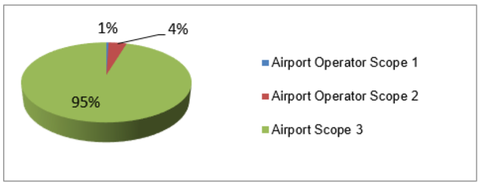
Appendix A: ACERT Report Output

Financial year 2018

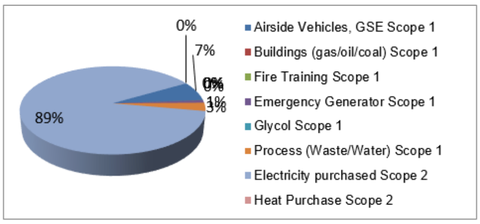
Identifier		ACI
Airport	Lanseria International Airport	
Airport Operator	Airport Operator Ltd	
Country	South Africa	
ACI Region	Africa	
Report Date	31/12/2018	
ACA-Level	ACA Level 3+	

Operational Data	2018
Passenger Movements	2 311 611
Aircraft Movements	62 824
Cargo (t)	623
Traffic Units (or WLU)	2 317 841
Airport Operator Staff (FTE)	380
Average distance to the City (km)	20

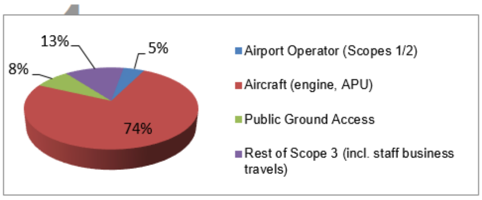
Greenhouse Gas Emissions		2018
Scope Break Down:		
Airport Operator Scope 1	(t CO2e)	584,4
Airport Operator Scope 2	(t CO2e)	4 662,9
Airport Scope 3	(t CO2e)	107 821,6
Total Gross Emissions	(t CO2e)	113 069,0
Offsets	(t CO2)	-
Total Net Emissions	(t CO2e)	113 069,0



Airport Operator Source Break Down:			
Airside Vehicles, GSE	Scope 1	(t CO2e)	372,0
Buildings (gas/oil/coal)	Scope 1	(t CO2e)	-
Fire Training	Scope 1	(t CO2e)	3,2
Emergency Generator	Scope 1	(t CO2e)	49,6
Glycol	Scope 1	(t CO2e)	-
Process (Waste/Water)	Scope 1	(t CO2e)	159,7
Electricity purchased	Scope 2	(t CO2e)	4 662,9
Heat Purchase	Scope 2	(t CO2e)	-
Total Scopes 1+2		**(t CO2e)**	**5 247,4**



Source Group Break Down:		
Airport Operator (Scopes 1/2)	(t CO2e)	5 247,4
Aircraft (engine, APU)	(t CO2e)	84 254,3
Public Ground Access	(t CO2e)	8 731,7
Rest of Scope 3 (incl. staff business travels)	(t CO2e)	14 835,6



Airport Carbon Neutrality Path		
Total required offsets (Scopes 1+2, Bus. Travel)	(t CO2e)	5 247,4
Airport Operator Carbon Offsets	(t CO2e)	-
Neutrality achieved	%	0,0%

Electricity Reporting		2018			
Airport Operator Electricity Use (incl renewables)	MWh	4 807	Scope 2: Location-based	(t CO2e)	4 662,9
Airport Tenant Electricity Use (incl renewables)	MWh	6 218	Scope 2: Market-based	(t CO2e)	-

Key Performance Indicators		2018	
Airport Operator Carbon Intensity	(t CO2e/FTE)	13,8	(Scopes 1 and 2)
Airport Carbon Intensity (Scopes 1+2)	(kg CO2e/pax)	2,27	(Scopes 1 and 2)
Airport Carbon Intensity (Scopes 1+2)	(kg CO2e/TU)	2,26	(Scopes 1 and 2)

Financial year 2019

Lanseria International Airport Greenhouse Gas Emissions Inventory 2019

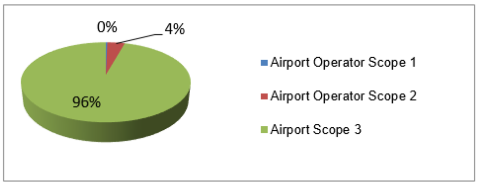
ACERT Version 5.1

by: Tania Chimhau, Master's Student (Mail: tania.chimhau23@gmail.com)

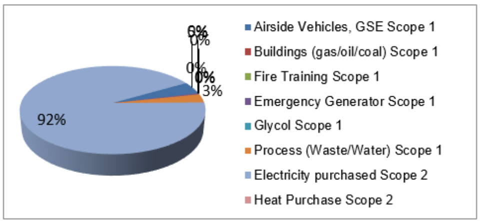
Identifier	ACI	Operational Data	2019
Airport	Lanseria International Airport	Passenger Movements	2 376 380
Airport Operator	Airport Operator Ltd	Aircraft Movements	64 343
Country	South Africa	Cargo (t)	902
ACI Region	Africa	Traffic Units (or WLU)	2 385 400
Report Date	31/12/2018	Airport Operator Staff (FTE)	363
ACA-Level	ACA Level 3	Average distance to the City (km)	20

Greenhouse Gas Emissions — 2019

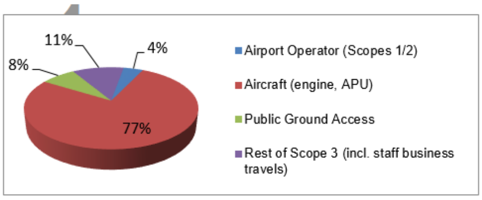
Scope Break Down:		
Airport Operator Scope 1	(t CO2e)	396,3
Airport Operator Scope 2	(t CO2e)	4 482,3
Airport Scope 3	(t CO2e)	107 689,9
Total Gross Emissions	(t CO2e)	112 568,6
Offsets	(t CO2)	-
Total Net Emissions	(t CO2e)	112 568,6



Airport Operator Source Break Down:			
Airside Vehicles, GSE	Scope 1	(t CO2e)	217,7
Buildings (gas/oil/coal)	Scope 1	(t CO2e)	-
Fire Training	Scope 1	(t CO2e)	1,4
Emergency Generator	Scope 1	(t CO2e)	21,3
Glycol	Scope 1	(t CO2e)	-
Process (Waste/Water)	Scope 1	(t CO2e)	155,9
Electricity purchased	Scope 2	(t CO2e)	4 482,3
Heat Purchase	Scope 2	(t CO2e)	-
Total Scopes 1+2		**(t CO2e)**	**4 878,7**



Source Group Break Down:		
Airport Operator (Scopes 1/2)	(t CO2e)	4 878,7
Aircraft (engine, APU)	(t CO2e)	86 291,5
Public Ground Access	(t CO2e)	8 575,1
Rest of Scope 3 (incl. staff business travels)	(t CO2e)	12 823,2



Airport Carbon Neutrality Path		
Total required offsets (Scopes 1+2, Bus. Travel)	(t CO2e)	4 878,7
Airport Operator Carbon Offsets	(t CO2e)	-
Neutrality achieved	%	0,0%

Electricity Reporting — 2019

Airport Operator Electricity Use (incl renewables)	MWh	4 621	Scope 2: Location-based	(t CO2e)	4 482,3
Airport Tenant Electricity Use (incl renewables)	MWh	5 978	Scope 2: Market-based	(t CO2e)	-

Key Performance Indicators — 2019

Airport Operator Carbon Intensity	(t CO2e/FTE)	13,4	(Scopes 1 and 2)
Airport Carbon Intensity (Scopes 1+2)	(kg CO2e/pax)	2,05	(Scopes 1 and 2)
Airport Carbon Intensity (Scopes 1+2)	(kg CO2e/TU)	2,05	(Scopes 1 and 2)

Financial year 2020

Lanseria International Airport Greenhouse Gas Emissions Inventory 2020

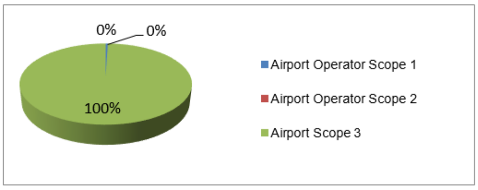
ACERT
Version 5.

by: Tania Chimhau, Master's Student (Mail: tania.chimhau23@gmail.com)

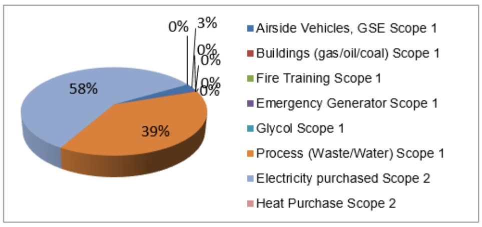
Identifier	ACI
Airport	Lanseria International Airport
Airport Operator	Airport Operator Ltd
Country	South Africa
ACI Region	Africa
Report Date	31/12/2018
ACA-Level	ACA Level 3+

Operational Data	202(
Passenger Movements	1 866 388
Aircraft Movements	51 073
Cargo (t)	516
Traffic Units (or WLU)	1 871 548
Airport Operator Staff (FTE)	36(
Average distance to the City (km)	2(

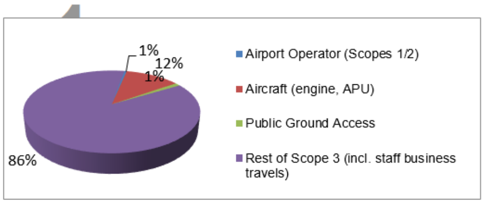
Greenhouse Gas Emissions		2020
Scope Break Down:		
Airport Operator Scope 1	(t CO2e)	2 783,5
Airport Operator Scope 2	(t CO2e)	-
Airport Scope 3	(t CO2e)	572 008,8
Total Gross Emissions	(t CO2e)	574 792,3
Offsets	(t CO2)	-
Total Net Emissions	(t CO2e)	574 792,4



Airport Operator Source Break Down:			
Airside Vehicles, GSE	Scope 1	(t CO2e)	190,2
Buildings (gas/oil/coal)	Scope 1	(t CO2e)	-
Fire Training	Scope 1	(t CO2e)	1,4
Emergency Generator	Scope 1	(t CO2e)	20,3
Glycol	Scope 1	(t CO2e)	-
Process (Waste/Water)	Scope 1	(t CO2e)	2 571,6
Electricity purchased	Scope 2	(t CO2e)	3 896,8
Heat Purchase	Scope 2	(t CO2e)	-
Total Scopes 1+2		**(t CO2e)**	**6 680,3**



Source Group Break Down:		
Airport Operator (Scopes 1/2)	(t CO2e)	2 783,5
Aircraft (engine, APU)	(t CO2e)	68 494,9
Public Ground Access	(t CO2e)	6 734,8
Rest of Scope 3 (incl. staff business travels)	(t CO2e)	496 779,1



Airport Carbon Neutrality Path		
Total required offsets (Scopes 1+2, Bus. Travel)	(t CO2e)	2 783,6
Airport Operator Carbon Offsets	(t CO2e)	-
Neutrality achieved	%	0,0%

Electricity Reporting		2020			
Airport Operator Electricity Use (incl renewables)	MWh	4 017	Scope 2: Location-based	(t CO2e)	3 896,
Airport Tenant Electricity Use (incl renewables)	MWh	5 978	Scope 2: Market-based	(t CO2e)	-

Key Performance Indicators		2020	
Airport Operator Carbon Intensity	(t CO2e/FTE)	7,7	(Scopes 1 and 2)
Airport Carbon Intensity (Scopes 1+2)	(kg CO2e/pax)	1,49	(Scopes 1 and 2)
Airport Carbon Intensity (Scopes 1+2)	(kg CO2e/TU)	1,49	(Scopes 1 and 2)