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ASSESSING CLIMATE CHANGE MITIGATION STRATEGIES IN MANUFACTURING INDUSTRIES: A CASE OF MATSAPHA INDUSTRIAL AREA, ESWATINI

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Assessing Climate Change Mitigation Strategies In Manufacturing Industries: A Case Of Matsapha Industrial Area, Eswatini

A thesis submitted to Pan African University in partial fulfillment of the requirements for the degree of Master of Science

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Submitted on: March 2025

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DEDICATION

This thesis is dedicated to my family. Without their support, I would not have been able to undergo it and complete it. Thank you.

DECLARATIONS

Student's Declaration

I hereby declare that this thesis is entirely my own work. Other's ideas and words have been properly cited. The thesis has not been submitted to another institution for the award of a degree, diploma, or certificate.

Signature Date: 24 March 2025

Supervisor's Declaration

I , Khaldoon A. Mourad, hereby declare that I supervised the preparation of this Master thesis submitted therein in accordance with the guidelines on supervision of Master thesis laid down by the Pan African University Institute of Water and Energy Sciences, Algeria.

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BIOGRAPHICAL SKETCH

Makhosazana was born in Eswatini, Lubombo region on the 25th of February 1995. From an early age, she showed a keen interest in nature, which gave her the nickname tree hugger. This later shaped her academic and professional journey, of which she is now an environmentalist.

Makhosazana pursued her education at the University of Eswatini and earned a BSc in Environlental Health Science. During her academic years, she often found herself in leadership positions and was elected the vice secretary for an environmental club.

After completing her education, she embarked on a professional journey in the health and safety industry in 2019. Over the years, she held various positions, including SHEQ Manager, her most recent professional role before enrolling at PAUWES. She has also volunteered as a communications manager for an NGO in Nigeria, as well as an NGO in Eswatini as a social media manager. She continues striving to make meaningful contributions to society.

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ABBREVIATIONS AND ACRONYMS

GHGs – Greenhouse gases

CO2 – Carbon dioxide

CH4 – Methane

UNFCCC – United Nations Framework Convention on Climate Change

HFCs - Hydrofluorocarbons

SO2 - Sulfur dioxide

NOx - Nitrogen oxides

NDC – Nationally determined contributions

IPCC – Intergovernmental Panel on Climate Change

NCDs - Non communicable diseases

WHO – World Health Organisation

VOCs - Volatile organic compounds

IPPU - Industrial processes and product use

UN – United Nations

NFFO - Non fossil fuel obligation

SLCPs - Short lived climate pollutants

NGOs – Non governmental organisations

PEF - Private enterprise federation

SDGs – Sustainable development goals

VNR - Voluntary national review

GDP - Gross domestic product

MTEA – Ministry of Environmental Affairs

GIS – Geographical Information System

SPSS - Statistical package for social sciences

MtCO2eq – Metric tons of carbon dioxide equivalent

GWP - Global warming potential

NCCC - National climate change committee

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ABSTRACT

Climate change mitigation in the manufacturing sector is crucial for reducing greenhouse gas (GHG) emissions and promoting sustainable industrial practices. In Eswatini, the industrial sector contributes the largest in GHG emissions countrywide. Therefore, this study assesses the extent of GHG emissions from manufacturing industries in the Matsapha Industrial Area, Eswatini, and evaluates their mitigation measures. Additionally, it explores the level of climate change awareness among industry stakeholders, employees, and local residents while identifying existing policies governing the sector. Data was collected through questionnaires and analyzed using SPSS. The findings indicate limited knowledge of climate change across stakeholders, a lack of formal policies regulating industrial emissions, and minimal employee training on climate-related issues. Furthermore, most industries are aware of climate change but do not consistently track their GHG emissions, and there is no awareness of carbon market mechanisms. These results highlight the need for comprehensive climate policies, increased stakeholder education, and structured emission monitoring frameworks to enhance climate change mitigation in the manufacturing sector.

Keywords: Climate Change Mitigation; Greenhouse Gas Emissions; Manufacturing Sector; Climate Change Awareness; Sustainable Industrial Practices

Makhosazana Ngci Masuku

Assessing climate change mitigation strategies in manufacturing industries: a case of Matsapha Industrial Area, Eswatini.

1. INTRODUCTION

1.1 Background

Climate change is a global phenomenon that has necessitated the action of the whole world (Fairweather et al., 2020). Significant changes in global temperatures and weather patterns throughout time are referred to as climate change (Zolnikov, 2019). Although scientific data suggests that human activities, including the combustion of fossil fuels and deforestation, have accelerated these changes at a rate never seen since the late 19th century, this is a natural phenomenon (Fairweather et al., 2020; MuhammaddMubeenn et al., n.d.). The rise in greenhouse gases (GHGs) in the atmosphere, especially carbon dioxide (CO2) and methane (CH4), is the main cause of the recent climate change. The greenhouse effect is a warming phenomenon caused by these gases' ability to retain heat from the sun. (Pisor & Jones, 2021). Therefore, an abundance of these GHGs in the atmosphere intensifies the work they do, of which without, would lead to a very cold planet. Climate change has far-reaching effects on both ecosystems and human health. It contributes to rising sea levels, more extreme weather events such as hurricanes and droughts, and shifts in biodiversity. Additionally, it disrupts essential resources such as clean water, air quality, and food security, exacerbating existing social and economic inequalities (Coplan et al., 2021; Evers & Pathirana, 2018; He et al., 2023). Climate change has been termed a global phenomenon as it has devastating effects and impacts all over the world.

As a result, international cooperation and initiatives to reduce the emissions of GHGs, especially CO2, have been addressed in the Paris Agreement and Kyoto Protocol by the United Nations Framework Convention on Climate Change (UNFCCC) (Balsara et al., 2019; Niñerola et al., 2020). Internationally, it has been agreed to limit the increase of the global temperature to 2^0C (Niñerola et al., 2020). However, even with the international agreements being established, GHGs emissions continued, with rates higher than before. The year 2010 saw the highest atmospheric emissions (Mitchell, 2017). Clearly, anthropogenic activities continued which put the globe at risk of the impacts of climate change. Climate change therefore does not only impact the earths' climate, but the livelihood of its' inhabitants as well as all types of development. This phenomenon has captured the globe, with mitigation and adaptation measures being the presented solutions to preventing further change in climate, as well as adjusting to the already existing changes.

Climate change affects the whole world, but not at the same severity. Africa is one of the continents that is significantly affected by climate change, which poses serious challenges to its agricultural productivity, water resources, and overall socio-economic stability. In West Africa, climate change has led to a decline of 6% in the yields of staple crops such as maize, sorghum, and rice (Khan, 2024).

Southern Africa is projected to experience a 15% to 50% reduction in agricultural productivity, worsening food insecurity. The impacts include increased temperatures and reduced rainfall, particularly affecting drier areas. The reliance on rain fed agriculture means that any changes in rainfall patterns can severely disrupt food production (MuhammaddMubeenn et al., n.d.). Climate change also exacerbates water scarcity issues across the continent. Southern Africa faces significant challenges with reduced rainfall and increased evaporation rates, impacting both agricultural irrigation and drinking water supplies (Fairweather et al., 2020).

The sectors that have been identified as contributing to climate change are the energy sector, agricultural sector, industrial sector which comprises of manufacturing and waste management, land use and forestry, as well as residential and commercial buildings. Carbon intensive industries, specifically energy and manufacturing industries, have been called out as the ones needing to adjust to low-carbon activities, since they are one of the main culprits of greenhouse gas emissions (Cadez & Czerny, 2016). The industry sector, which includes manufacturing industry, accounted for more than a quarter of greenhouse gas emissions worldwide in 2010 (Mitchell, 2017), making it one of the key sectors that need to transition to low-carbon if reducing climate change is the end goal. Manufacturing industries emit GHGs by burning fossil fuels for heat provision as well as other industrial processes that emit GHGs when converting materials into goods. An indirect method of emission from manufacturing industries is using electricity generated from fossil fuels (Budget Office, n.d.).

Certain manufacturing processes, such as cement production, involve chemical reactions that release CO_2 as a byproduct. An example is the calcination of limestone (calcium carbonate) which produces lime (calcium oxide) and CO_2 (Budget Office, n.d.). Industries that use refrigeration systems may emit potent greenhouse gases like hydrofluorocarbons (HFCs), which have a much higher global warming potential than CO_2. Manufacturing industries also produce waste that decomposes in landfills can produce methane, a potent greenhouse gas (Haas et al., 2015). Industries can also get rid of waste through incineration. Burning waste can release CO2 and other pollutants into the atmosphere. Since manufacturing industries use raw materials, the transportation of these raw materials to manufacturing sites and finished products to consumers often involves vehicles that emit greenhouse gases (Sathyamoorthi et al., 2023). Furthermore, extracting raw materials often involves energy-intensive processes that emit greenhouse gases such as mining and logging (Stern, 2014).

Mitigating emissions from manufacturing industries is crucial for several interconnected reasons. For starters, manufacturing industries are significant contributors to GHG emissions, particularly CO2 and CH4. Combating climate change and its effects, including extreme weather, rising sea levels, and biodiversity loss, requires reducing these emissions. (Li, Wang, et al., 2021). Emissions from manufacturing can include harmful pollutants like particulate matter, sulfur dioxide (SO2), and nitrogen oxides (NOx), which degrade air quality and can lead to respiratory diseases and other health issues in surrounding communities (Li, Wang, et al., 2021). Therefore, mitigating these emissions also has health benefits for people living in close proximity to these manufacturing industries. Moreover, exposure to industrial emissions can result in serious health problems, including respiratory illnesses, cardiovascular diseases, and even cancer (Avenyo & Tregenna, 2022). Mitigating these emissions protects public health and lowers medical expenses due to illnesses brought on by pollution.

Implementing emission reduction strategies often leads to more efficient manufacturing processes. This can reduce operational costs through energy savings and waste minimization, enhancing overall productivity (Y. Chen & Jin, 2023). As governments worldwide tighten regulations on emissions, industries that proactively mitigate their emissions are better positioned to comply with laws and avoid potential fines or sanctions (B. Xu & Lin, 2016). There is also a social responsibility aspect to mitigating GHG emissions. Industries that take steps to reduce their environmental impact can enhance their reputation among consumers, investors, and stakeholders. This commitment to sustainability can lead to increased customer loyalty and market competitiveness. By reducing emissions, manufacturing industries contribute to the well-being of local communities, fostering a healthier environment for residents (Li, Wang, et al., 2021). Several countries are part of international agreements aimed at reducing global emissions such as the Paris Agreement. Industries, especially manufacturing industries play a critical role in meeting national targets for emission reductions, contributing to global efforts against climate change (Avenyo & Tregenna, 2022; Y. Chen & Jin, 2023; Li, Wang, et al., 2021).

There are a number of mitigation measures that industries can employ to reduce their greenhouse gas emissions. Industries can reduce energy intensity using emerging technologies. Industries can also increase efficiency in material use through re-using and recycling. Waste reduction and energy recovery is another measure industries can use to mitigate against greenhouse gas emission (Mitchell, 2017).

This study therefore sought to identify how manufacturing industries in Matsapha Industrial area Eswatini, contribute to greenhouse gas emissions by assessing the used mitigation measures to reduce their greenhouse gas emissions, if any. Furthermore, it sought to assess the policies that govern the industrial sector, if any, as well as the climate change knowledge among industrial stakeholders. Subsequently, policy implications from observed results were proposed.

1.2 Problem statement

Climate change has had extreme impacts on many African countries including Eswatini (Kingdom of Eswatini Update of the Nationally Determined Contributions, 2021a). Like the rest of the world, Eswatini is experiencing a rise in temperature. Figure 1 shows the annual mean temperature for Eswatini, which is evidently increasing.

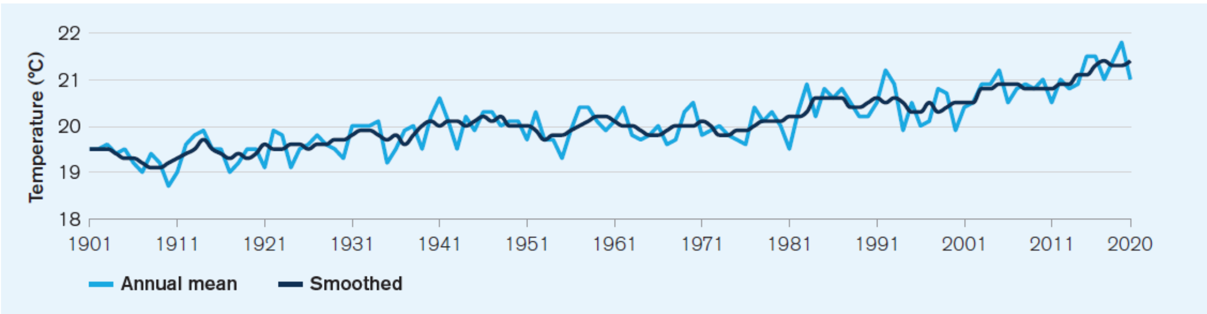

Figure 1: Annual mean temperature for Eswatini (ESWATINI CLIMATE RISK COUNTRY PROFILE, 2021a).

As a result, Eswatini experiences a number of climate change related impacts. Table 1 shows the different climate induced disasters that Eswatini has faced.

Table 1: Disasters experienced in Eswatini

Natural Hazard 1900–2020	Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 USD)
Drought	Drought	7	500	2,354,000	1,739
Epidemic	Bacterial Disease	2	62	3,677	0
	Parasitic Disease	1	80	0	0
Flood	Flash Flood	1	11	400	0
	Riverine Flood	2	0	274,500	50
Storm	Tropical cyclone	1	53	632,500	54,152
Wildfire	Forest fire	1	2	1500	0

With these disasters comes cascading impacts that affect the livelihood of Swati people. Figures 2, 3 and 4 show these impacts in drought, flash floods and hailstorms that have affected the country.

Figure 2: Drought in Eswatini

Figure 3: Flash floods in Mbabane, Eswatini.

Figure 4: Hail in Eswatini.

Compared to the global north, Eswatini contributes very little to global GHG emissions. However, inaction comes at a cost therefore mitigation is vital just as much as adaptation. Eswatini has experienced the impacts of climate change in the form of changing rainfall patterns, consistent droughts, cyclones, hailstorms and heatwaves. These impacts have cascaded to affecting the livelihoods of Swati people, most of whom depend on agriculture and livestock rearing. Key economic sectors are affected by climate change. The industry sector is not affected by climate change as much as other sectors like agriculture. Conversely, it is one of the sectors that must transition to lower the impacts of climate change. The National Climate Change Policy clearly states that the industrial sector contributes 45% of the emissions from Eswatini, which made this sector the largest contributor (THE KINGDOM OF SWAZILAND MINISTRY OF TOURISM AND ENVIRONMENTAL AFFAIRS NATIONAL CLIMATE CHANGE POLICY, 2016, n.d.-a)

This insinuates that for Eswatini to dramatically reduce its' GHG emissions, the industrial sector needs to shift towards low-carbon activities. Therefore, this research assessed the employed mitigation measures in manufacturing industries in the Matsapha industrial area. This particular study area was selected as it is the largest industrial zone in Eswatini that houses the majority of the country's manufacturing industries.

1.3 Significance of study

This study of assessing mitigation measures in manufacturing industries is crucial. The study will help industrial stakeholders prioritize mitigation efforts by identifying these vulnerabilities. It also seeks to raise these stakeholders' understanding of climate change and encourage behavioral adjustments that support sustainability objectives. The study's importance stems from its capacity to enable the manufacturing sector to assume a pivotal function in curbing greenhouse gas emissions on a national scale. Manufacturing industries can make a significant contribution to the nation's overall goals for reducing emission through efficient mitigation techniques. Additionally, this endeavour will help Eswatini fulfil its' Nationally Determined Contributions (NDCs) in accordance with the terms of the Paris Agreement.

Furthermore, applying mitigation measures on the manufacturing industries in Matsapha Industrial area will reap environmental and socioeconomic benefits. Mitigation measures directly lower CO_2 and other greenhouse gas emissions, which are critical for combating climate change. For instance, implementing low-carbon technologies can reduce CO_2 emissions significantly, contributing to global climate goals. Emission reductions also lead to lower concentrations of harmful air pollutants such as particulate matter, NO_x, and SO_2. Implementing energy-efficient practices and technologies not only reduces emissions but also conserves natural resources, leading to more sustainable manufacturing processes. Enhanced air quality from reduced emissions translates into better health outcomes for communities, leading to decreased healthcare costs associated with pollution-related illnesses. The employees of the different manufacturing industries in Matsapha can have improved health outcomes associated with respiratory illnesses. Transitioning to low-emission technologies can stimulate job creation in emerging sectors focused on sustainability and environmental protection, fostering economic growth. Companies that adopt sustainable practices often enjoy improved public perception, which can enhance brand loyalty and attract environmentally conscious consumers. Eswatini is recommended to impose stricter environmental regulations, as it is part of international agreements on climate change. As this will occur, industries that proactively implement mitigation measures are better positioned to comply, avoiding potential fines and enhancing their market competitiveness.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this study was to assess the capacity of the industrial sector, specifically manufacturing industries, in dealing with climate change issues. This study aimed to find out how the manufacturing industries in Eswatini contribute to greenhouse gas emissions and how they mitigate against such. It gauged whether the industrial sector is proactive in mitigating climate change and provided recommendations in the policy sector after results were obtained. Eswatini does not have stringent laws that manufacturing industries are to follow in reducing their GHG emissions. Therefore, this study sought to push the government into taking such actions.

1.4.2 Specific objectives

i. Identify how manufacturing industries contribute to greenhouse gas emissions,
ii. Identify and assess the used mitigation measures by manufacturing industries to reduce their greenhouse gas emissions
iii. Assess the policies that govern the industrial sector, if any,
iv. Assess climate change knowledge among industrial stakeholders.

1.5 Research Questions

i. How do the manufacturing industries contribute to greenhouse gas emissions?
ii. What are the mitigation measures used by manufacturing industries to reduce their greenhouse gas emissions?
iii. What are the policies that govern the industrial sector?
iv. Are industrial stakeholders knowledgeable on climate change?

2. LITERATURE REVIEW

2.1 General Overview

This chapter looks at pertinent research initiatives, studies, literature reviews, and supplementary notes on studies that are pertinent to the current investigation. The chapter starts by outlining the theoretical framework and conceptual framework of the study and proceed to climate change and manufacturing industries. Following is an overview of mitigation strategies used in manufacturing industries. Other details in the Chapter include policies governing climate change and challenges faced by manufacturing industries in implementing mitigation strategies.

2.2 Theoretical Framework

The theoretical framework of the study is supported by the concepts of corporate governance and compliance, analyzing how employee obligations are shaped by adherence to compliance requirements, such as those related to safety, the environment, and ethics. This theory also emphasizes how important it is for regulatory and policy frameworks to institutionalize different roles and expectations within enterprises. When studying companies, researchers try to find common structures that are employed to address issues, boost productivity and efficiency, and satisfy stakeholders. The framework for comprehending how groups function is provided by organizational theories, which are developed using the patterns that have been found. Best practices for optimal functioning can be found through research.

To differing degrees of success, various theories that center on various aspects of organizational interactions and structure have been applied to organizations, as is the case with all fields of sociological inquiry. Sociologist Amitai Etzioni originally proposed the concept of compliance theory in 1969, but it was evident in 1961 (Frölicher et al., 2016). Compliance theory is not to be confused with the same-named legal theory. It centers on the interaction between actors inside an organization, namely the organizational representatives and lower-level participants.

More precisely, the theory aims to investigate the dynamics of relationships between people in positions of authority within an organization and others who are subservient to them. Subordinates who play official or informal roles within the organization are considered lower-level participants. A parishioner is an informal lower-level participant in a church, whereas a low-ranking enlistee in the military would be seen as a low-level formal player in a military hierarchy. As long as someone exhibits strong devotion to one of the three characteristics of participation—involvement, subordination, or performance—they are considered lower-level participants (Frölicher et al., 2016).

2.3 Conceptual Framework

The underlying ideas, variables, connections, and presumptions that direct the scholarly investigation are contained in a conceptual framework. It creates the theoretical foundation and offers a prism through which data may be comprehended and examined by researchers. A conceptual framework offers a foundation for comprehending the issue under study by drawing on pre-existing ideas, models, or bodies of knowledge. It establishes the characteristics of the study, identifies pertinent variables, formulates research questions, and directs the choice of suitable data processing methods and processes.

2.3.1 Climate change

The term "climate change" describes the earth's prolonged warming, which is mostly brought on by an increase in greenhouse gas concentrations in the atmosphere. Greenhouse gases (GHGs) include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are essential for regulating the planet's temperature. The heat from the sun is trapped by these gases, keeping it from escaping back into space. This process, known as the greenhouse effect, is necessary to keep Earth's temperature habitable. However, since the Industrial Revolution, the concentration of these gases has significantly increased due to human activities including burning fossil fuels, deforestation, and industrial operations (Capstick & Pidgeon, 2014).

Human activity is mostly to blame for the rise in GHG emissions. The majority of anthropogenic greenhouse gas emissions have traditionally come from highly developed countries, but this is beginning to change as other countries experience rapid economic development (Capstick & Pidgeon, 2014). In addition to being a scientific problem, climate change has repercussions for the economy, society, geopolitics, and health. It is a complex issue that impacts local and international politics, the legal system, and public health (Capstick & Pidgeon, 2014; Pielke, n.d.).

Because of its complexity and the global reach of its effects, climate change is regarded as one of the largest market failures (Stern, 2014). Along with other climate-related problems, growing GHG levels are also causing sea levels to rise, temperatures to rise, extreme weather events to occur more frequently, and disturbances to ecosystems and biodiversity. The environment and human societies could be severely impacted by these changes (Capstick & Pidgeon, 2014; Stern, 2014)

2.3.2 Drivers of climate change

Human activities continue to have a significant impact on the climate due to changes in elements that affect the earth's radiative balance. These elements, referred to as radiative forcings, include of variations in greenhouse gas concentrations, tiny airborne particles (aerosols), and the earth's surface's reflectance (Bibi & Jamil, 2021). The primary source of climate change during the industrial age has been and continues to be human activity. The relatively minor net increase in radiative forcing resulting from natural variables, such as variations in solar energy and the cooling impact of volcanic eruptions, has been greatly outweighed by the increase in radiative forcing caused by these activities (Kearsley & Riddel, 2010).

Human-produced aerosols play a vital and intricate role in the climate system because of their radiative effects on the atmosphere, the surfaces of snow and ice, and the formation and properties of clouds (Assenza et al., 2015). Throughout the industrial age, the combined forcing of aerosol–cloud and aerosol–radiation interactions has, with high confidence, been negative (cooling), balancing a large amount of greenhouse gas forcing, which is currently the main human contribution. The global average of this offset has declined in recent decades, despite increasing trends in aerosol emissions or abundances in some regions.

Numerous positive and negative feedback processes are present in the interrelated Earth, atmosphere, and ocean system, and they have the power to either amplify or attenuate the system's reactions to external factors like humans and the elements. According to Lv and Xu (Lv & Xu, 2019), these feedbacks function throughout a variety of timescales, from very short to extremely long. During the industrial period, net radiative forcing has contributed to global warming, and these feedbacks have significantly amplified the effect. The net feedback impact has been favorable throughout the industrial age and will remain so in the upcoming decades, despite the fact that some of these feedbacks are highly unpredictable.

2.3.3 Impact of climate change

The physical environment of Earth and the living things that inhabit it are both negatively impacted by climate change. The environment of the physical planet Earth is impacted by all changes that occur to plants, animals, and human life. Human settlements around the ocean, woodlands, and coral reefs are especially susceptible to climate change. According to Rehman et al., one possible consequence of climate change is an increased vulnerability to chemical contamination (Rehman et al., 2022). While the majority of climate change's effects are probably going to be negative, some areas may see improvements in health. For instance, milder winters may result in fewer deaths and health incidents linked to temperature.

2.3.3.1 Temperature

Elevated Earth's surface and upper oceanic layers temperatures are linked to the current climate change. Surfaces on land are warming more quickly than those on the water. More water vapor can be retained in a warmer atmosphere, increasing average precipitation overall. The Earth's temperature has risen by roughly 0.7°C in the last 70 years. The quantity of warm days and nights has increased since 1950, whereas the quantity of cold days and nights has decreased (Rehman et al., 2022). More warming has occurred since 1976 than at any other point in the previous a millennium. There are extremes in temperature at any given time. Currently, the average world temperature is approximately 15.0°C. The surface temperature is currently increasing by about 0.2°C per ten years. The Intergovernmental Panel on Climate Change (IPCC) predicts that global mean temperatures would increase by 0.9 to 5.4°C by 2100, depending on various emission scenarios.

2.3.3.2 Mountain glaciers and lakes

The melting of mountainous glaciers and the acceleration of ice loss in Greenland and Antarctica are two effects of climate change. Certain glaciers hold significant religious and symbolic value for the indigenous populations. Globally, lakes are freezing for shorter periods of time. Thousands of lakes could lose their winter ice cover in a few decades (Sigman, n.d.).

2.3.3.3 Hurricanes and rainstorms

Because of the warming of the ocean, climate change encourages stronger and more deadly hurricanes as well as heavier rainstorms. Research indicates that during the last few decades, there has been a rise in the frequency of large storms (Categories 4 and 5) as a result of climate change (Zafar et al., 2019). Increased energy from warmer ocean temperatures allows hurricanes to intensify, which could lead to an increase in the frequency of strong storms.

2.3.3.4 Droughts

Numerous biological and physical phenomena have an impact on the complicated and varied phenomenon of drought. One of the most costly natural calamities is drought. Droughts are becoming more often and severe due to climate change, particularly in subtropical regions where deserts are encouraged to expand. Changes in precipitation patterns brought about by climate change may lead to decreased rainfall in some locations (Ortiz-Bobea, 2020). Reduced precipitation exacerbates drought conditions by causing lower soil moisture, decreased surface water availability, and water scarcity. This will lead to population migration, disturbed livelihoods and increased food insecurity.

2.3.3.5 Impact of climate change on health

Due to heat stress, climate change has a variety of effects on human health. Because of this occurrence, both direct and indirect effects are anticipated. These include changes in the geographic range and rate of disease vector (insect, tick, and rodent) transmission; food- and water-borne illnesses; and the frequency of illnesses linked to aeroallergens and air pollution (H. Chen et al., 2019). Climate change is predicted to increase the prevalence of infectious diseases like HIV/AIDS, cholera, and tuberculosis, as well as dengue, yellow, and malaria fevers. Climate change has the potential to worsen non-communicable diseases (NCDs), acute and chronic respiratory conditions such chronic obstructive pulmonary disease and asthma, diabetes, cardiovascular disease, malignancies, and malnutrition (Bashir et al., 2020).

There may be an increase in the frequency of both direct and indirect effects, such as heatwave and flood-related mortality. There may currently be over 150,000 deaths annually related to climate change, and by 2030, there is concern that this number may double globally (Frölicher et al., 2016). Furthermore, according to data from the World Health Organization (WHO), under a high emission scenario, the number of heat-related fatalities among the elderly (65 years of age and older) is expected to rise to 70 per 100,000 by 2080. The situation is concerning since an additional Monash University study—regarded as the largest survey in the world—adjusts 5 million deaths per year to high temperatures.

2.4 Climate change and manufacturing industries

The manufacturing sector faces both opportunities and challenges as a result of climate change, which affects many areas of operations, supply chains, resource management, and sustainability standards.

2.4.1 Greenhouse Gas Emissions

The burning of fossil fuels for energy production and industrial operations is the main cause of carbon dioxide emissions from the manufacturing sector. One of the main greenhouse gases that contributes to global warming is CO2. It traps heat in the atmosphere. Apart from carbon dioxide, manufacturing processes can also generate harmful greenhouse gases like methane and nitrous oxide, which have a much higher potential to cause global warming than carbon dioxide (Harper et al., 2018). While certain chemical reactions and combustion processes can produce nitrous oxide, methane is frequently released into the atmosphere by industrial operations like waste management and agriculture.

Certain manufacturing operations are known to release significant volumes of greenhouse gases, including the production of steel, cement, chemicals, and refining. These sectors frequently involve chemical reactions and energy-intensive procedures that release greenhouse gases like CO2 (Khattak et al., 2020).

2.4.2 Energy Consumption

Energy-intensive manufacturing sectors sometimes need large volumes of fuels, heat, and electricity to run machinery, equipment, and industrial operations. The use of fossil fuels as a primary source of energy increases greenhouse gas emissions, which exacerbates climate change. Fossil fuels, including coal, oil, and natural gas, are used to power several manufacturing processes. When these fuels burn, they release greenhouse gases like CO2.

Fossil fuel burning is one of the main causes of climate change and global warming. Depending on the fuel and technique utilized, the energy consumption of manufacturing businesses leads to the direct emissions of various pollutants and greenhouse gases, mostly CO2. The manufacturing sector's entire carbon footprint is influenced by these emissions. Large volumes of electricity are frequently needed in manufacturing operations for machinery, lighting, heating, and cooling, among other functions. Depending on the percentage of renewable and non-renewable energy sources in the grid, the power production mix used by industrial facilities may have an impact on greenhouse gas emissions (Wang et al., 2021).

2.4.3 Resource Extraction and Utilization

Manufacturing companies' extraction and consumption of raw materials contribute to habitat degradation, deforestation, and resource depletion, all of which can worsen climate change by upsetting ecosystems and biodiversity. To create things, the manufacturing sector depends on the exploitation of raw materials such metals, minerals, biomass, and fossil fuels (Zhang et al., 2015). Due to ecosystem degradation and carbon release, the extraction process may have major negative effects on the environment, including as habitat destruction, deforestation, soil erosion, and water contamination.

Raw material extraction, transportation, and processing are frequently energy-intensive operations that release greenhouse gases into the atmosphere. Particularly energy-intensive processes like mining and cement production need large energy inputs, which results in carbon dioxide emissions that fuel climate change. Energy-intensive procedures that produce greenhouse gas emissions are frequently used in the extraction, transportation, and processing of raw materials (Wang et al., 2021).

2.5 Type of manufacturing industries

Manufacturing industries encompass a wide range of sectors that produce goods through various processes.

2.5.1 Automotive Industry

This industry produces parts and accessories in addition to cars, trucks, and other types of vehicles. In order to produce vehicles, assembly lines, factories, and cutting-edge technologies are involved. The manufacture and usage of automobiles is the primary way in which the automotive sector contributes significantly to greenhouse gas emissions (Esso & Keho, 2016). Internal combustion engines in vehicles use a lot of fossil fuels, which produces greenhouse gas emissions during burning.

This industry manufactures cars, trucks, and other vehicles in addition to parts and accessories. Assembling lines, factories, and state-of-the-art technology are needed to make automobiles. The principal method by which the automotive industry greatly increases greenhouse gas emissions is through the production and use of automobiles (Esso & Keho, 2016). Vehicles using internal combustion engines burn a lot of fossil fuels, which releases greenhouse gases when they burn.

2.5.2 Textile and Apparel Industry

This sector produces apparel, accessories, textiles, and fabrics. It includes procedures like weaving, spinning, dying, and making clothes. Global Industry Analysts, Inc. projects that by 2017, the textile machinery industry would grow to a value of US$22.9 billion (Osman et al., 2020). The textile and apparel industries are vital to the global economy, creating millions of jobs in around 200 nations. The generation of textile waste, the high energy, water, and chemical consumption of the textile and clothing industries, as well as the release of microfibres into the environment during laundering, all contribute to the industries' detrimental ecological imprint (Kim & Park, 2016).

Eight to ten percent of the world's carbon emissions come from the apparel and footwear sectors, which is more than the combined emissions of the shipping and aviation sectors. Their vast supply chains and energy-intensive manufacturing procedures are to blame for this (Zuiderveen et al., 2024). Furthermore, it has been discovered that up to 20% of industrial wastewater contamination is caused by textile dyeing and finishing (Twinoburyo & Odhiambo, 2018). The textile industry's energy-intensive production methods and complex supply chain for transporting fabrics and clothing from production sites, which are usually in developing nations, cause it to contribute nearly 10% of global greenhouse gas emissions, or roughly 1.2 billion tonnes of CO2 equivalent, to the atmosphere annually (Y. Chen & Jin, 2023). The growing demand for clothing, exacerbated by the expansion of the fast fashion business model, necessitates a constant flow of natural resources.

By 2050, the fashion industry is expected to contribute almost 25% of global carbon emissions (Zhang et al., 2015). The extraction of raw materials, manufacture, distribution, and end-of-life disposal are only a few of the supply chain steps where the garment and textile industries greatly contribute to climate change. The extensive use of pesticides, fertilizers, and water in conventional cotton growing contributes to soil deterioration and greenhouse gas emissions. Energy-intensive, gas-emitting technologies are needed to produce synthetic fibers like nylon and polyester. The energy-intensive and fossil fuel-dependent processes used in the spinning, weaving, and dyeing of textiles result in carbon emissions.

When manufacturing textiles, the industry utilizes a variety of chemicals, some of which are bad for the environment and cause pollution. Overproduction and fast fashion create a lot of textile waste, most of which ends up in landfills where it breaks down and releases greenhouse gases. Microplastics released by synthetic fibers during washing have an adverse effect on ecosystems and contribute to marine pollution.

2.5.3 Food and Beverage Industry

The manufacturing of packaged goods, beverages, and food products is included in the food and beverage business. Food delivery, packaging, and processing are all included. Through a variety of activities related to food production, distribution, consumption, and waste management, the food and beverage business considerably contributes to climate change (Zhang et al., 2015). The ability of forests to sequester carbon dioxide is diminished when they are converted to agricultural land for food production, releasing stored carbon. Methane is a powerful greenhouse gas that is produced during the raising of cattle for meat and dairy products. This gas contributes to global warming. Fossil fuels are the energy source for agricultural machinery, irrigation systems, and food processing facilities, which results in greenhouse gas emissions.

Decomposition of organic waste causes major greenhouse gas emissions from losses in the food supply chain, from farm to fork. Food waste at the consumer level wastes resources used in food production and increases methane emissions in landfills (Velders et al., 2015).

2.5.4 Chemical Industry

The manufacturing, delivery, and use of chemical goods all include activities that the chemical industry contributes significantly to climate change. Numerous chemicals, such as industrial chemicals, medicines, polymers, and specialty compounds, are produced by the chemical industry. Strict safety procedures and intricate chemical processes are involved (Wild, 2009). Chemical plants use chemical processes, like chemical reactions, to create new compounds in a variety of reaction vessels. Many times, the reactions employ catalysts and are conducted at high pressures and temperatures in specialized equipment designed to withstand corrosion.

Several methods, such as distillation, are used to separate the products of these reactions.

Because chemical production processes are energy-intensive and frequently dependent on fossil fuels, greenhouse gasses like CO_2 are released. Methane and nitrous oxide, two greenhouse gases, are released during certain chemical reactions in manufacturing processes. Volatile organic compounds (VOCs) and other pollutants that contribute to air pollution and climate change can be released during industrial operations through the use of solvents and different chemical reactions (Abdulla et al., 2019). Waste products from the manufacturing of chemicals may release greenhouse gases when disposed of or treated

2.6 Evidence of manufacturing industries contributing to climate change

Due to human activity, machines were used and previously manual processes were mechanized, which contributed significantly to the industrial revolution's involvement in the past 200 years in the emission of greenhouse gases (Prăvălie & Bandoc, 2018). Thus, the industrial revolution began with technological advancements, economies that moved quickly, geographical expansions, an unparalleled rate of population growth, urban emergencies, and a shift in the world's scientific system.

The industry and the energy supply sector were responsible for about 24% and 34% of the net anthropogenic GHG emissions in 2019 respectively. Relative emission shares of the industry and building sectors grow when emissions from the production of heat and electricity are reallocated to the sectors that use the final energy. According to this frame (Pétron et al., 2014), industry is responsible for the majority (34%) of emissions in 2019.

About a quarter (23%) of greenhouse gas emissions in the US come from the manufacturing, food processing, mining, and building sectors. The situation is even worse in Europe, where the sector is among the top emitters of greenhouse gases on the continent, with an annual total of 880 million tonnes of carbon dioxide equivalents released. These direct emissions come from a variety of sources, such as the on-site burning of fossil fuels for electricity and heat, the use of non-energy sources, and chemical reactions used in the production of cement, steel, and iron. These include fluorinated gases, nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2). As these gasses envelop the Earth, they trap more solar energy, causing the globe to warm.

Humans and all other Earthly living forms are at serious risk from this (Shobande & Shodipe, 2019). Three-quarters of all deaths related to weather, climate, and water occurred in Africa between 1970 and 2021. However, just 40% of Africans have access to early warning systems, which is the lowest percentage globally. That is what the recently proposed Early Warnings for All Action Plan for Africa aims to address (H. Chen et al., 2019).

2.7 Overview of mitigation strategies used in manufacturing industries

Climate change mitigation is the term used to describe any action taken by institutions, governments, or private citizens to reduce or eliminate greenhouse gas emissions or to enhance carbon sinks that remove these emissions from the atmosphere. Because of these gases' capacity to store solar heat, our planet's atmosphere stays warm. Despite the rise in emissions from 1990 to 2019, several mitigation strategies have aided in the removal of emissions in the fight against climate change. These include the establishment of a plantation development fund to promote plantation development in the private sector, the implementation of a forest plantation development program aimed at planting trees on degraded forest lands, and a government policy that forbids the export of round logs in order to enhance local timber processing (Bataille et al., 2018).

Other measures include industry-wide GHG emission controls, as those in the Industrial Processes and Product use (IPPU) sector, which have reduced emissions by roughly 11.8% between 1990 and 2019 (Gasser et al., 2015); increasing the use of renewable energy; clean cooking and lighting; energy efficiency in homes, businesses, and industries; innovative waste management through waste reduction, recycling, and reuse; natural gas recovery and use; and restrictions on gas flaring in the oil and gas industry.

2.7.1 Energy Efficiency Improvements

Enhancing energy efficiency has the potential to drastically lower greenhouse gas emissions and energy use. Energy management systems, process optimization, and equipment upgrades can all help achieve this (Mwinkom et al., 2021).

Limitations: Energy-efficient solutions can have significant upfront expenses. Refitting existing buildings can be difficult as well, and depending on the particular sector and procedures, energy-saving techniques may or may not be beneficial.

2.7.2 Renewable Energy Adoption

Reducing dependency on fossil fuels and carbon emissions can be achieved by making the switch to renewable energy sources including hydroelectric, solar, and wind power (Zhou et al., 2024).

Limitations: The location and time of year can have an impact on the reliability and availability of renewable energy sources. It could be necessary to invest in and modify infrastructure in order to integrate renewable energy into manufacturing operations.

2.7.3 Waste Reduction and Recycling

Recycling initiatives and waste reduction techniques can help cut down on waste production, preserve resources, and lessen pollution in the environment (H. Chen et al., 2019).

Limitations: Difficulties could include managing intricate waste streams, finding practical recycling solutions for certain materials, and making sure hazardous garbage is disposed of properly. The viability of recycling programs can also be impacted by logistical and financial factors.

2.7.4 Sustainable Supply Chain Management

Reducing the environmental effects of material sourcing, transportation, and production processes can be achieved by promoting sustainability throughout the supply chain (Kim & Park, 2016).

Limitations: It might be difficult to monitor and guarantee that sustainability requirements are being followed throughout international supply chains. Manufacturers may find it difficult to strike a balance between cost and efficiency concerns and sustainability aspirations.

2.7.5 Green Technologies and Process Innovation

Reducing carbon footprint and improving environmental performance can be achieved by implementing green technology, such as low-emission technologies, cleaner production techniques, and advanced manufacturing processes.

Limitations: Changing to green technologies would need a large financial commitment as well as specialized knowledge. The adoption of new technologies can also be influenced by operational restrictions and compatibility with current infrastructure (Dafermos et al., 2018).

2.7.6 Carbon Offsetting and Emissions Trading

To counteract the emissions caused by manufacturing, investments in initiatives that capture or lower greenhouse gas emissions are made. Companies can purchase and sell carbon credits through emissions trading in order to reach emission reduction targets (Dafermos et al., 2018).

Limitations: The legitimacy and additionality of offset programs determine how effective carbon offsetting is. Challenges with emissions trading could include unpredictability in regulations, market volatility, and monitoring problems.

2.7.7 Regulatory Compliance and Carbon Pricing

Manufacturers can be encouraged to lower emissions, increase efficiency, and implement sustainable practices by laws, carbon pricing schemes, and environmental policies (Anastasiou et al., 2014).

Limitations: Manufacturers may face challenges related to competition, regulatory complexity, and compliance costs. Long-term planning can also be impacted by uncertainties regarding policy changes and regulatory frameworks.

2.7.8 Circular Economy Practices

Adopting circular economy principles such as product reuse, remanufacturing, and resource recovery can promote resource efficiency, reduce waste, and lower environmental impact.

Limitations: Transitioning to a circular economy model may require changes in business models, supply chain relationships, and consumer behaviour. Investment in reverse logistics and circular design can pose challenges for some industries (Wendling, 2019).

2.8 Importance of mitigation strategies

By adopting sustainable practices, cutting emissions, and fostering resilience in the face of climate-related difficulties, the manufacturing sector plays a critical role in combating climate change. Manufacturers may help create a future that is more resilient and sustainable by including climate considerations into their plans and processes (Abdulla et al., 2019).

Global ecosystems and biodiversity are threatened by climate change. By putting mitigation techniques into practice, we can safeguard biodiversity, maintain the balance of ecosystems that support life on Earth, and safeguard natural habitats. The effects of climate change on human health include the spread of diseases, water scarcity, air pollution, and extreme weather. Globally, mitigation initiatives support community well-being by lowering health risks (Harper et al., 2018). Crop failures, food shortages, and an increase in food poverty can result from agricultural systems being disrupted by climate change. By fostering resilience in the agricultural sector, mitigation techniques help guarantee food security for both the current and future generations. Through facilitating the shift to low-carbon economies, generating green jobs, and advancing clean technologies, mitigation measures support sustainable development.

The economy and the environment both gain from this drive toward sustainability. Significant economic losses may arise from the effects of climate change, including resource scarcity, sea level rise, and extreme weather events. Societies can lower the costs of climate-related disasters and increase their ability to withstand future hazards by putting mitigation policies into practice (Palmer, 2019). The distribution, quality, and availability of water are all impacted by climate change, which makes managing water resources more difficult. Mitigation measures assist in preserving water resources, lessening water stress, and guaranteeing communities' long-term access to clean water. Vulnerable communities are disproportionately impacted by climate change, which also makes social inequality worse.

Equality and social justice are taken into account by effective mitigation plans, which seek to reduce the disproportionate effects on vulnerable groups and increase climate resilience for all. Innovation in sustainable behaviors, climate-resilient infrastructure, and clean energy technology is fueled by mitigation initiatives. Effective climate change mitigation is made possible by cooperative initiatives at the local, national, and international levels that promote information exchange and group action. Globally, countries have pledged to cut back on their greenhouse gas emissions and work together to tackle climate change. According to Sinsel et al. (Sinsel et al., 2020), putting mitigation plans into practice is essential to achieving these global agreements and climate targets.

2.9 Successful implementation of mitigation strategies

These case studies show how putting mitigation methods into practice in the manufacturing sector can result in noticeable drops in carbon emissions. Some of these strategies include switching to renewable energy, streamlining supply chains, increasing energy efficiency, and applying sustainable practices. Manufacturing enterprises may lessen their environmental effect while simultaneously improving their competitiveness and long-term viability in a low-carbon economy by embracing innovation and integrating sustainability into their operations.

2.9.1 Tesla Motors - Renewable Energy Adoption

One of the top producers of electric vehicles, Tesla Motors, has made significant investments in adopting renewable energy at its factories. To run their business on renewable energy, they have installed energy storage devices and solar panels.

By switching to renewable energy, Tesla has lowered its carbon impact considerably. The company's efforts to use renewable energy have reduced carbon emissions linked to the amount of power used in industrial processes. In an effort to reduce the carbon footprint associated with each mile that its products and their components travel across the Tesla supply chain, the company plans to keep raising the percentage of renewable energy used at its plants (Bohensky et al., 2016). As a business, Tesla is committed to producing renewable energy. Tesla is focused on solar energy in particular, and the company has released cutting-edge solar panels and solar roof tiles for both home and commercial use.

Between 2012 and 2021, the company's solar panels generated more energy than its vehicles and factories combined. Apart from reducing emissions and averting blackouts, Tesla solar panels can be set up to act as a backup in case the grid fails (Bohensky et al., 2016). Additionally, the company claims that compared to many fossil fuel alternatives, its operating costs are lower per megawatt-hour. By encouraging the growth of solar power, Tesla makes it possible for individuals and companies to generate their own electricity with the least possible impact on the environment.

2.9.2 Unilever - Sustainable Supply Chain Management

The global consumer goods corporation Unilever has included sustainability into its supply chain management procedures. In order to encourage sustainable procurement, cut waste, and boost energy efficiency, they collaborate closely with suppliers. Throughout its value chain, Unilever has reduced carbon emissions as a result of its sustainable supply chain activities. Reducing the environmental effect of its manufacturing activities has been accomplished by Unilever through collaboration with suppliers to implement sustainable practices. The commitment to lessen carbon footprint and boost social effect is the result of this connection. Sustainability is seen as a catalyst for raising sales while boosting performance, leveraging quality, cutting expenses, and improving reputation (Sebos et al., 2023). With the use of cutting-edge technology for performance data collection and analysis, Unilever works with suppliers and other strategic partners to minimize the environmental effect of its end-to-end supply chain operations.

2.9.3 Interface Inc. - Circular Economy Practices

Global carpet maker Interface Inc. has adopted circular economy ideas through the implementation of recycling programs and a product take-back program. The company switched to a sustainable business model in the mid-1990s, moving away from the conventional industrial paradigm of producing modular carpets. By 2017, Interface closes the loops in its business processes and concentrates on innovation in circular business models. "By 2020, we want to be the first company that, through our actions, demonstrates to the entire industrial world what sustainability means in all its dimensions: People, Process, Product, Place, and Profits. In the process, we will become restorative through the power of influence." This is Interface's vision.

Mission Zero, the company's pledge to end any adverse effects Interface may have on the environment by 2020, reflects this. In order to fulfill its sustainability strategy, Interface has closed both the biological and technical cycles in a circular economy model, functioning as an ecosystem. In order to reduce waste and resource consumption, they recycle used carpets into new goods (Khan, 2024).

The mining and manufacturing of raw materials have resulted in a reduction of carbon emissions thanks to Interface's circular economy initiatives. Interface has significantly reduced its carbon footprint by encouraging a closed-loop system and reusing materials.

2.9.4 Patagonia - Waste Reduction and Recycling

Patagonia, an outdoor apparel brand, has made recycling and waste reduction a top priority in their production processes. Patagonia has been working to reduce the amount of virgin material they use and prevent clothing from ending up in landfills. Patagonia has saved 4,300 metric tonnes of CO2 this season by using recycled materials in 94% of its collection. They saved enough CO2 to power at least 500 households for a year, according to Patagonia. The business has resorted to recycling both pre- and post-consumer items in order to make this impact. Clothing that was headed for a landfill as well as fabric and yarn waste get a new lease of life thanks to these recycling methods.

Since fewer than 1% of discarded clothing is recycled into new products annually, Patagonia's recycling project is truly impactful and unique. They have put in place initiatives for recycling textiles, cut down on packaging waste, and encouraged product repair and reuse (Y. Chen & Jin, 2023).

Carbon emissions related to resource extraction and production processes have decreased thanks to Patagonia's waste reduction and recycling initiatives. Patagonia has significantly reduced its carbon footprint by encouraging circularity and decreasing trash output.

2.10 Awareness, Knowledge and Perceptions among industrial stakeholders

In a research work conducted by Sebos et al. (Sebos et al., 2016), the goal was to ascertain the degree of understanding, perceived values, suggestions, knowledge requirements, and expectations of important Greek stakeholders (public administration and private actors operating at the national, regional, and local levels) regarding climate change and its effects. The major players in both the public and business sectors believe that the biggest issue facing the world now is climate change. It is significant, nonetheless, that waste management is the top challenge facing Greece according to the stakeholders; this suggests that more work needs to be done to advance the circular economy, especially at the local and regional levels.

Bohensky et al. (Bohensky et al., 2016) conducted surveys with 124 stakeholders of varying levels at the onset of four multi-stakeholder workshops on climate adaptation. The study was conducted in Indonesia. Inquiries were made on the difficulties they saw in their area, observations made about climate change, feelings they connected with it, opinions about its causes, risks and readiness for it, and future timeframes they connected with it.

When the top three challenges were merged, well-being ranked highest overall. Participants initially listed food security and climate change as their top challenges. The majority of participants agreed that climate change was occurring, but those who worked at higher organizational levels were more likely to blame human factors for it than those who worked at lower levels, who were more likely to believe it was a product of nature.

Findings from a study by Sebos (Sebos et al., 2023) show that, in the opinion of the stakeholders, connections between local policy at the national and regional levels and climate change adaptation are necessary. The findings show that there is no integration plan or method to help with climate change adaptation. Few persons are generally recognized as authority on climate change policy, despite the fact that there has been some adaptation to the phenomenon. The difficulties and possibilities of involving important Indonesian stakeholders are also covered in this study.

2.11 Policies governing Climate change

The worldwide challenge of lowering greenhouse gas emissions, minimizing the effects of climate change, and making the transition to a more resilient and sustainable future depends heavily on policies controlling climate change. To combat climate change, the majority of important policies are frequently enacted and put into practice globally.

2.11.1 International Agreements

The 2015 adoption of the Paris Agreement. An international agreement on climate change that is legally binding is the Paris Agreement. On December 12, 2015, during the United Nations (UN) Climate Change Conference in Paris, France, it was adopted by 196 Parties. It became operative on November 4, 2016.

Its main objective is to "limit the temperature increase to 1.5°C above pre-industrial levels" and to "hold the increase in the global average temperature to well below 2°C above pre-industrial levels." Nonetheless, international leaders have emphasized in recent years how important it is to keep global warming to 1.5°C by the end of this century.

This is because the IPCC of the United Nations has warned that beyond the 1.5°C barrier could have far more severe climate change effects, including an increase in the frequency and severity of heatwaves, droughts, and rainfall. Global warming must be limited to 1.5°C by 2025 at the latest, and greenhouse gas emissions must decrease by 43% by 2030. The implementation of the Paris Agreement necessitates substantial social and economic transformation, according to the latest scientific results. In their internationally determined contributions, or NDCs, nations specify the actions they will take to reduce their greenhouse gas emissions in order to meet the goals of the Paris Agreement. Furthermore, nations specify in their NDCs the actions they intend to take to improve resilience in order to adjust to the consequences of climate change (Harper et al., 2018).

The Paris commitment is a major step forward in the global climate change process because it unites all nations under a legally binding promise to combat climate change and prepare for its effects. It requires nations to create and update Nationally Determined Contributions (NDCs) to reduce greenhouse gas emissions.

2.11.2 Renewable Energy Promotion

Emissions and reliance on fossil fuels can be considerably decreased by policies that promote the use of clean energy sources including hydroelectric, solar, and wind power. Reducing dependency on fossil fuels is at the heart of the Korean government's new energy policy. In 2008, 2.4% of Korea's total energy consumption came from renewable sources. The Korean government intends to increase this percentage to 11% by 2020 through a number of legislative initiatives. China's tremendous economic growth in recent decades has made it one of the world's biggest consumers of energy and emitters of greenhouse gases.

Their government had to enact new energy laws to support renewable energy technology because of the rapid economic expansion and high rate of energy consumption (Pfeiffer & Mulder, 2013). These days, the Chinese government mostly offers pricing incentives, tax incentives, and subsidies. The promotion of renewable energy technologies in China has advanced significantly in recent years thanks to these governmental instruments. When the UK power market was first liberalized in 1989, nuclear energy was not included in this process. Following the 1990 liberalization of the energy market, the first non-fossil fuel obligation (NFFO) was enacted.

This act's primary goals were to promote nuclear power and clean energy sources (Prăvălie & Bandoc, 2018). Additionally, this act mandated that power distribution firms buy electricity generated by nuclear power plants and renewable energy sources. However, at the time, over 90% of the budget was allocated to the development of nuclear energy due to the significance of nuclear energy, leaving the remaining portion for renewable energy sources.

2.11.3 Monetary policy

Monetary policy is recognized as a useful instrument for reducing CO2 emissions since it is thought to be a novel and important predictor of economic growth. Any countries' monetary authorities might successfully carry out monetary policy by responding to macroeconomic concerns by controlling the money supply and interest rates. An economy's monetary policy is dictated by the correlation between the total money supply and interest rates. Monetary policy changes may have an impact on economic outcomes that drive environmental quality, including innovation, economic growth, aggregate domestic consumption spending, energy consumption, financial market development, and openness in international trade (Twinoburyo & Odhiambo, 2018).

The relevance of monetary policy for carbon abatement to the sustainable development of the environment is being studied empirically more and more. According to Dafermos

(Dafermos et al., 2018), the credit mechanism may facilitate financial stability as a result of monetary policy's effect on climate change. For the cases of the United States, China, and Nigeria, Shobande and Shodipe, (Shobande & Shodipe, 2019) investigate how energy-related policies affect the impact of carbon emissions disclosure. They also demonstrate how monetary policy favorably influences the promotion of climate change control measures through the interest rate mechanism of the monetary pass-through. Nonetheless, a number of studies contend that using monetary policy to slow down climate change could result in carbon.

2.11.4 Eswatini’s National Climate Change Policy

The national climate change policy of Eswatini was put into effect in 2016. The aims of this policy are to establish a framework that facilitates the effective implementation of adaptation and mitigation measures for climate change, improve investments in low-carbon, inclusive, and climate-resilient green growth, raise public awareness and education about climate change, and establish mechanisms for coordinating and forming partnerships in the fight against climate change (THE KINGDOM OF SWAZILAND MTEA NATIONAL CLIMATE CHANGE POLICY, 2016, n.d.-b).

2.11.5 Climate and clean air

As a partner of the Climate and Clean Air Coalition since 2019, the Kingdom of Eswatini has contributed to projects pertaining to heavy-duty vehicles, HFCs, and agriculture. The Ministry of Tourism and Environment of Eswatini declared its interest in creating an inventory and reduction strategy for short-lived climate pollutants (SLCPs) as part of the NDC Partnership, which was established in 2020. In order to support its National Climate Change Policy and help Eswatini's climate action be in line with the objectives of sustainable development, poverty eradication, and adaptive capacity as outlined in its National Development Plan, the Coalition worked with the country throughout 2021 to finalize assessments of greenhouse gases, soil, water, and pollutants. Eswatini's National Climate Change Policy addresses the major industries, transportation, waste management, energy, and agriculture that contribute to SLCP emissions (Mavimbela et al., 2021).

2.12 Challenges in implementing climate change mitigation strategies

Chen and Jin's study from 2023 (Y. Chen & Jin, 2023) examined evaluations of the effects of climate change and various management measures. It found that there are a number of implementation gaps and issues with these interventions. The most significant of them was inadequate funding, which prevents efforts to adapt to the effects of climate change, such as droughts, floods, and sea level rise, because the intended funding does not reach the subnational (district) level. Additionally, local efforts to adapt to climate change, particularly in agriculture, are receiving less finance and are given less attention than mitigation operations (such as those in forestry and energy). The revised NDC indicate that between US$ 9.3 and US$ 15.5 billion would need to be invested for implementation efforts from 2020 to 2030 in order to achieve effective adaptation.

It is expected that these will come from sources in the public, private, and carbon markets as well as from throughout the world. The conditional programs need the remaining US$ 5.4 billion to be implemented until 2030, while the unconditional programs of action will need US$ 3.9 billion of the total. Even with the restricted funding, it is difficult to keep track of financial inflows because many national organizations get cash for combating climate change from different sources that infrequently go via a centralized hub like the Ministry of Finance. For instance, funds given to civil society and non-governmental organizations (NGOs) involved in climate change initiatives are not reported to a central tracking body.

Duplication of climate change actions is another result of poorly coordinated communication between the government, donors, and other civil society organizations. In addition to financial constraints, there are other hindrances to adaptation, such as insufficient awareness of the plethora of options accessible to diverse vulnerable groups about the diverse expressions of climate impacts. Other factors include insufficient knowledge about climate change and building capacity through early warning systems, education, and other means to improve adaptation.

The adoption of suggestions from local populations already feeling the effects of climate change is hampered by the often top-down approach to climate change decision-making, which limits adaptation and mitigation efforts at learning from local expertise. Despite these and other obstacles, significant lessons might be drawn from them that could be applied to forging successful future pathways toward better adaptation. In order to address the difficulties associated with implementing policies and to create effective and long-lasting routes for adaptation projects, policymakers will need to give this greater thought. In order to fulfil her international obligations, accomplish long-term national development plans, and meet global sustainable development goals, Ghana anticipates that the revised NDC will be essential.

One method to do this could be to increase the skills and competencies needed to mobilise the required funds for local climate action through climate financing. Even though the private sector has historically provided insufficient funding for climate change projects, the Ghanaian government collaborates with the private sector through the Private Enterprise Federation (PEF) to successfully implement the SDGs. In order to actively contribute to the achievement of SDG targets, such as those for climate change mitigation and adaptation as well as sustainable production and consumption, the private sector must actively integrate sustainability concepts into their business operations, according to the Voluntary National Review (VNR) Report on the Implementation of the 2030 Agenda for Sustainable Development.

3. METHODS

3.1 Overview

This study employed a descriptive research design to assess climate change mitigation measures in the manufacturing industries of the Matsapha Industrial Area, Eswatini. The target population included industry representatives, employees, and local residents, with purposive sampling used for key informants and random sampling for employees and residents. Primary data was collected using structured questionnaires, which covered topics such as climate change awareness, industry-specific mitigation strategies, employee training, and policy frameworks. The collected data was analyzed using SPSS (Statistical Package for the Social Sciences), utilizing descriptive statistical tools such as frequency distributions and percentages to interpret the findings. Ethical considerations were maintained by ensuring voluntary participation, confidentiality, and informed consent. This methodology provided a structured approach to understanding the extent of GHG emissions, the level of climate change awareness, and the existing regulatory framework within the industrial sector.

3.2 Study Area

The Kingdom of Eswatini (formally Swaziland), is located in the southeast of Africa and is landlocked and hilly. With a total land area of 17,360 square kilometres (km), Eswatini is the smallest nation in the southern hemisphere. It is landlocked and shares eastern borders with Mozambique and South Africa. Eswatini is divided into four main administrative regions: Manzini, Hhohho, Lubombo and Shiselweni as seen in Figure 5. The study area is Matsapha Industrial site is found in Manzini region. A number of manufacturing industries are located within this industrial site as it is the biggest industrial site in Eswatini, and the town Matsapha, is situated at the hub of the country (ESWATINI CLIMATE RISK COUNTRY PROFILE, 2021b).

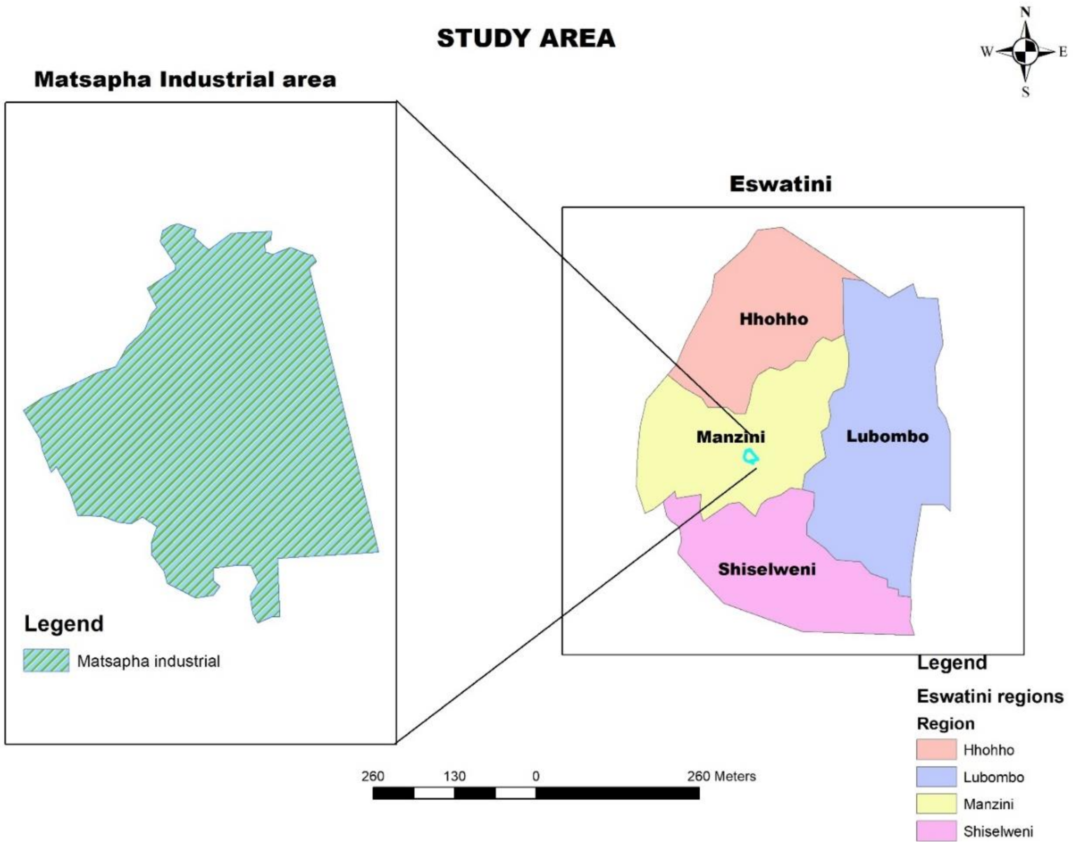

Figure 5: The study area map

The overall climate of Eswatini is classified as subtropical, with cold, dry winters (April to September) and wet, hot summers (about 75% of the yearly rainfall occurring between October and March). The Highveld's physiographic zones are sub-humid and temperate, whereas the Lowveld's are semi-arid and warm.

There are four recognized ecosystems of eSwatini:

a) Montane grasslands,

b) Savanna-woodland mosaic

c) Forests, and

d) Aquatic systems.

The country's centre and lower regions are dominated by savanna-woodlands, which are followed by montane grasslands, which are primarily found in the Highveld. Adaptation is crucial to dryland management because drylands are especially susceptible to the effects of climate change. Drylands make up 54% of Eswatini and include the entire Lower Middleveld, Eastern and Western Lowveld, as well as portions of the Upper Middleveld and Lubombo Range. The damp semi-arid zone in the southern Lowveld is the driest region in eSwatini. The northern Lowveld is home to the majority of the intermediate dry sub-humid zone. The Lower Middleveld, the majority of the Lebombo, and a tiny portion of the Upper Middleveld comprise the driest region in the Drylands.

As of 2020, Eswatini's population stands at 1.16 million, growing at a pace of 1.0% each year. With an annual growth rate of 2.2% in 2019 and -1.6% in 2020, the GDP peaked in 2013 at 6.4% and reached $3.9 billion in 2020. By 2030 and 2050, respectively, it is anticipated that 26.5% and 33.8% of the population will reside in urban areas, up from the current 24%. Eswatini falls under the lower middle-income category. Nonetheless, 90% of Eswatini's imports come from South Africa, and the nation imports 80% of its electricity. Additionally, the Eswatini Lilangeni is based on the South African Rand (Drought Resilience Profiles | Eswatini, n.d.)

Services and industry contribute for 52.4% and 37.5% of the nation's GDP, respectively. Sugar continues to be the most significant source of foreign exchange earnings, notwithstanding the manufacturing sector's diversification since the 1980s. For the vast majority of Eswatini's people and the country's economic growth, agriculture is the most crucial industry. But from more than 30% of GDP at independence (1968), the sector's participation dropped to 13% in 1989 and 10% in 2009. A significant portion of the nation's export revenue comes from agricultural output, which serves as the raw material basis for around one-third of the value-added commodities produced in the industrial sector. Approximately 77% of all cattle are owned by smallholder farmers, making livestock production another important agricultural sector. Droughts and excessive rangeland grazing have reduced productivity, which has led to a decrease in cattle numbers in recent years. Population growth has also contributed to a rise in resource demand. The foundation of eSwatini's economy is agriculture, and in order to meet its development objectives and lessen its level of vulnerability to climate change, the nation must diversify its economic activities (Kingdom of Eswatini Update of the Nationally Determined Contributions, 2021b)

Matsapha Industrial area predominantly houses factories. However, there are also residential areas, a shopping centre, businesses, schools and warehouses. Thus the area has been divided into 6 wards for better management by the Matsapha Municipality as shown in Figure 6. Manufacturing industries are spread throughout the 6 wards (Mavimbela et al., 2021).

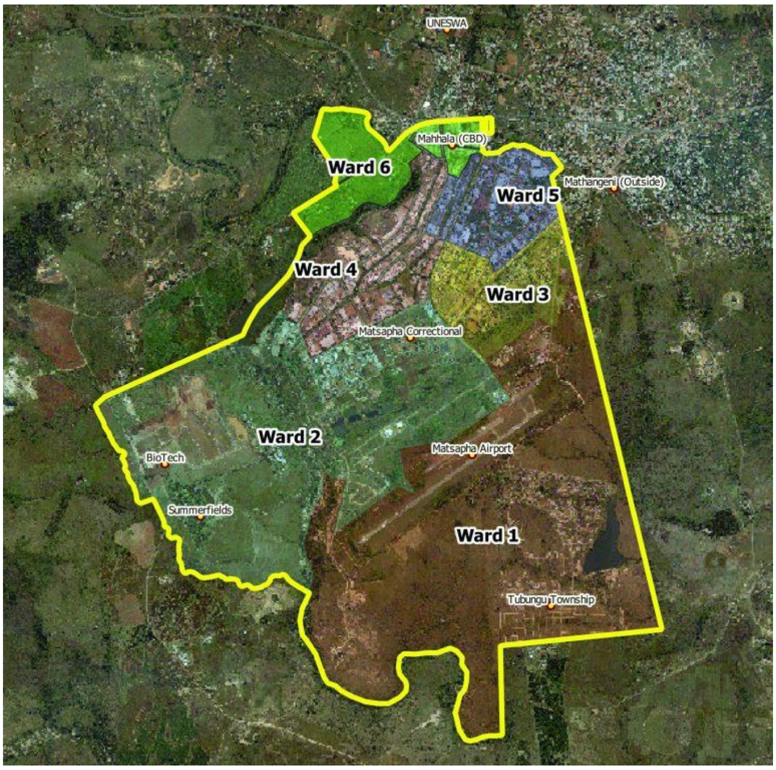

Figure 6: Matsapha Industrial area division wards

3.3 Methodology

3.3.1 Research Design

This study utilized a qualitative research design, specifically employing a survey methodology. Surveys are an effective means of gathering data from a large population in a systematic manner, allowing researchers to analyze trends, patterns, and relationships between variables.

3.3.2 Population and Sample

Manufacturing industries

The target population for this study consisted of manufacturing industries, manufacturing industries employees, residents in Matsapha industrial area and relevant Ministries. The Matsapha Municipality was contacted for the number of manufacturing industries in the area, of which the total came to 23. All manufacturing industries were involved in this study, together with 3 employees from each industry.

Matsapha Industrial site residents

The population for Matsapha was found to be 35 000 during the day, with 6 100 for during the night. For the purposes of this study, the day time population was considered. With 50% of the population being under 18, only the remaining 50% was considered for this study.

Cochrans formula was used to calculate the sample size (Cochran, 2005). With a 95% confidence level and a 5% precision, the sample was 385.

$N = z^2 . p. (1 – p)/ e^2$

where :

- *N = required sample size*
- *Z = Z-value (the number of standard deviations from the mean, based on the confidence level, e.g., 1.96 for 95% confidence)*
- *p = estimated proportion of the population (if unknown, 0.5 can be used for maximum sample size)*
- *e = margin of error (the desired level of precision)*

The sampling method used was convenience sampling.

Ministry

One ministry was identified as a stakeholder for this particular study, Ministry of Tourism and Environmental Affairs (MTEA). This is the ministry solely responsible for climate change issues in Eswatini.

3.3.3 Data collection

The survey instrument used were four different structured questionnaires designed to collect data from Industries, Employees, Residents and Ministries.

Manufacturing industries

A list of manufacturing industries was solicited from Matsapha Municipality. The phone GPS locator was used to get the correct coordinates of the industries, after which a map was produced using ArcGIS and Google Earth to demonstrate the locations of these industries within the Matsapha Industrial area map. To collect data, a questionnaire was used, which consisted of seven sections, namely;

- ✓ Background information
- ✓ General awareness and emissions knowledge
- ✓ Emission sources and energy use
- ✓ Waste management and emissions
- ✓ Supply chain and logistics
- ✓ GHG reduction strategies and goals
- ✓ Future actions and support

The questions were primarily multiple-choice questions with two explanatory ones. The questionnaire was pre-tested on 5 industries to ensure clarity and reliability.

Employees

The questionnaire consisted of five sections, namely;

- ✓ Demographic information
- ✓ Awareness of climate change
- ✓ Manufacturing industry's role
- ✓ Personal knowledge and practices
- ✓ Perceptions and suggestions

The questions were primarily multiple-choice questions. The questionnaire was pre-tested on 10 employees to ensure clarity and reliability.

Residents

The questionnaire consisted of five sections, namely;

- ✓ Demographic information
- ✓ Awareness of climate change
- ✓ Impact of manufacturing industries
- ✓ Personal perception and responsibility
- ✓ Suggestions for improvement

The questions were primarily multiple-choice questions. The questionnaire was pre-tested on 40 residents to ensure clarity and reliability.

Ministries

The questionnaire consisted of six sections, namely;

- ✓ Policy scope and objectives
- ✓ Policy components and requirements
- ✓ Policy enforcement and compliance
- ✓ Policy effectiveness and outcomes
- ✓ Policy challenges and improvement areas
- ✓ Future policy development and support

The questions were primarily multiple-choice questions with one explanatory one. The questionnaire was pre-tested on the ministry to ensure clarity and reliability.

Data were collected over a three-month period from November 2024 to January 2025. Participants were invited to complete the survey through paper-based surveys distributed in their specific areas. Informed consent was obtained before participants began the survey, and they were assured of the confidentiality and anonymity of their responses.

3.3.4 Data Analysis

In this study, data analysis was conducted using SPSS version 27, focusing on descriptive statistics to summarize and present the findings effectively. Frequency analysis was employed to examine the distribution of categorical variables, providing insights into the occurrence of different responses. To enhance data visualization, bar graphs were generated to depict comparisons across categories, making it easier to identify patterns and trends. Additionally, pie charts were used to illustrate proportional distributions, offering a clear representation of relative frequencies. This approach ensured a comprehensive and easily interpretable presentation of the data, facilitating meaningful conclusions.

4. RESULTS AND DISCUSSIONS

4.1 Overview

This chapter details the results obtained from questionnaire responses. The chapter is structured to present the findings in a logical and coherent manner, addressing each research objective in turn. Statistical analyses, where applicable, are presented to support the interpretation of the data. Following the presentation of the results, a discussion section for each objective analyzes the key findings in relation to the research questions, theoretical framework, and relevant prior research. This chapter serves as the core of the study, providing the empirical evidence to support the conclusions drawn in Chapter 5.

4.2 Assessing the Impact of Manufacturing Industries on Greenhouse Gas Emissions

The first objective for this study was to identify how manufacturing industries contribute to greenhouse gas emissions. A total of 21 industries participated in the study, as seen in Figure 7.

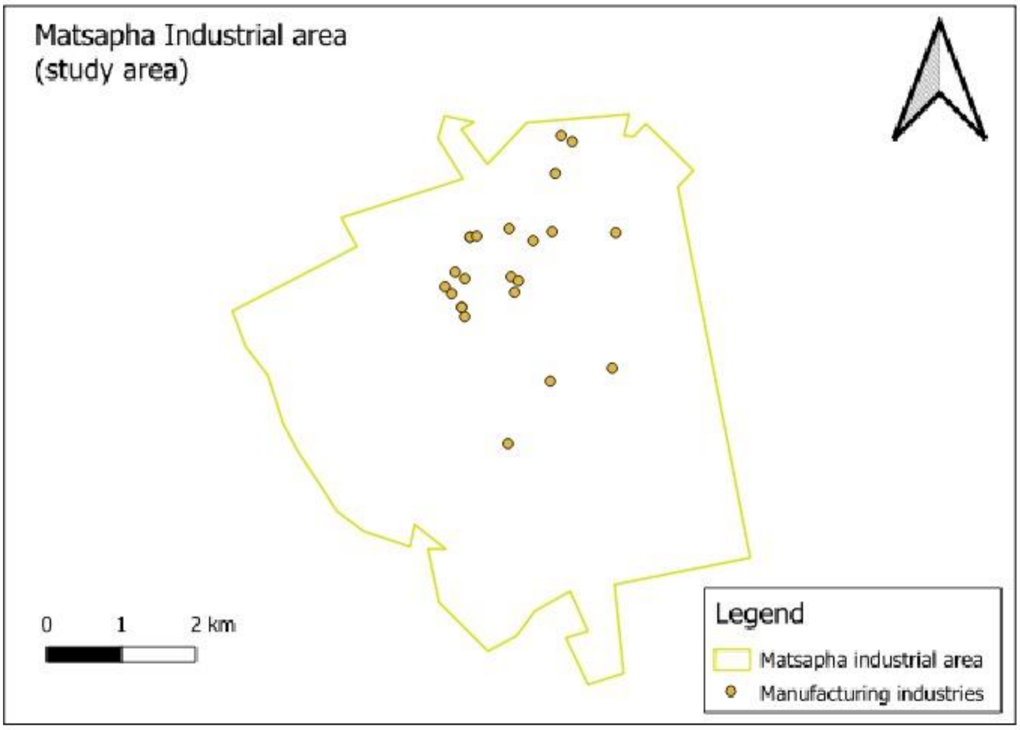

Figure 7: Location of manufacturing industries in Matsapha Industrial Area

For starters, background information was gathered through the questionnaires. It revealed that a majority of the manufacturing industries are under the food and beverage classification (as seen in figure 8), with 11 out of 21 being in that category. Four of the manufacturing industries aligned with the ‘other’ option in the questionnaires, with 2 of them falling under iron and steel, 1 in refrigeration manufacturing and 1 in oil and gas classification.

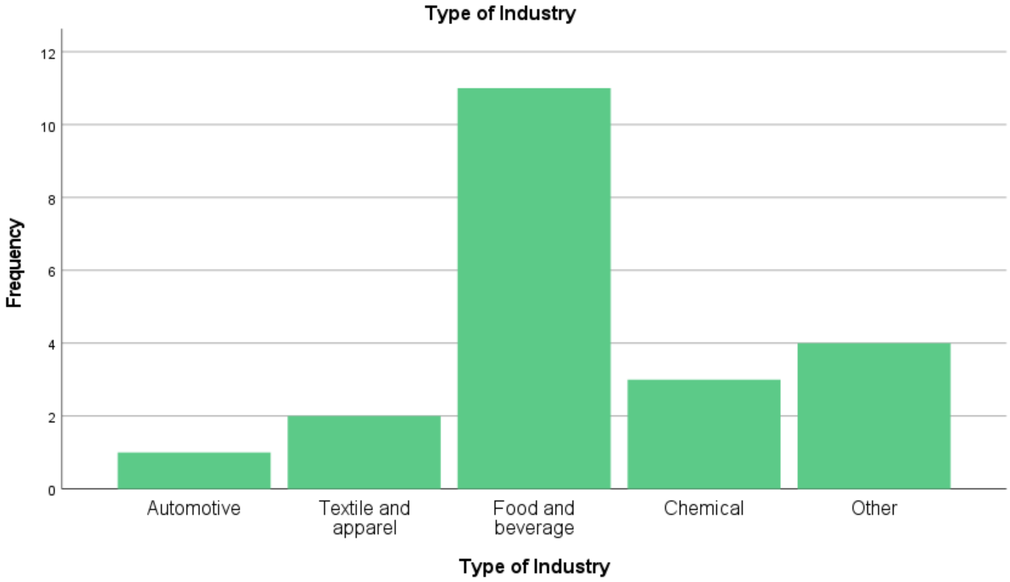

Figure 8: Types of manufacturing industries in Matsapha Industrial area.

For the purposes of obtaining data for objective 1, manufacturing industries were asked to select all sources of greenhouse gas emissions that applies to their activities. All of the industries selected electricity usage as a source (Figure 9). This is both a direct and indirect source of GHG emissions (Yousefi et al., 2021). For manufacturing industries, it is an indirect source of emission because they only use the end product, electricity, for electrical purposes such as lighting and heating. It is also a direct source of emission because they contribute to fossil fuel usage. Electricity in Eswatini is coal based (*National Energy Policy*, n.d.), which is a non-renewable energy source. This is a direct source of the emission of carbon dioxide, a greenhouse gas. The second highest GHG emission source was transport, as seen in Figure 9. This is to be expected as these are manufacturing industries, therefore they still need to transport their goods to end users.

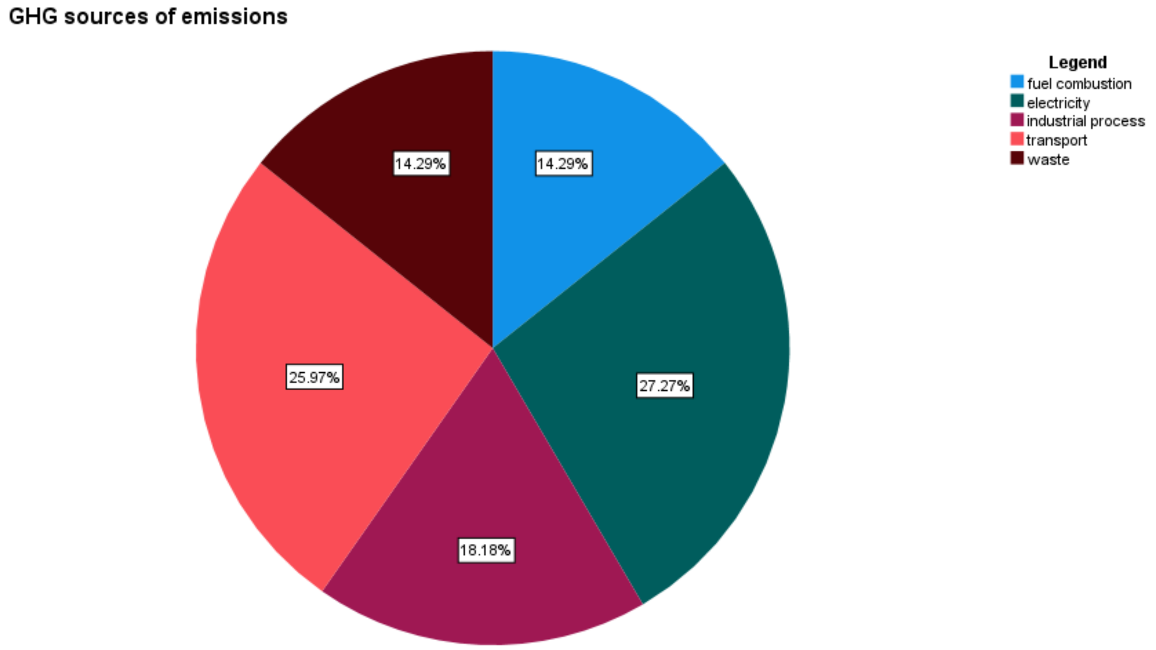

Figure 9: Sources of GHG emissions from manufacturing industries

A subsequent question was asked in terms of transport, as to what type of transportation they use for distribution. All of the manufacturing industries use road transportation, which are trucks. Only 7 use rail in addition to road transport. This also attests to the fact that they operate in Africa and not outside of the continent. With a majority of the manufacturing industries using vehicles for distribution, none use low emission vehicles. Rather they perform shipment consolidation as a strategy to reduce GHG emission from logistics.

Other sources of GHG emissions from manufacturing industries were waste and fuel combustion. The industries generate different types of waste, with plastic being produced the most, followed by hazardous and organic, with 31%, 26% and 18% of the industries producing these types, respectively. Furthermore, types of fuels used were given for manufacturing industries to select all that applied to them.

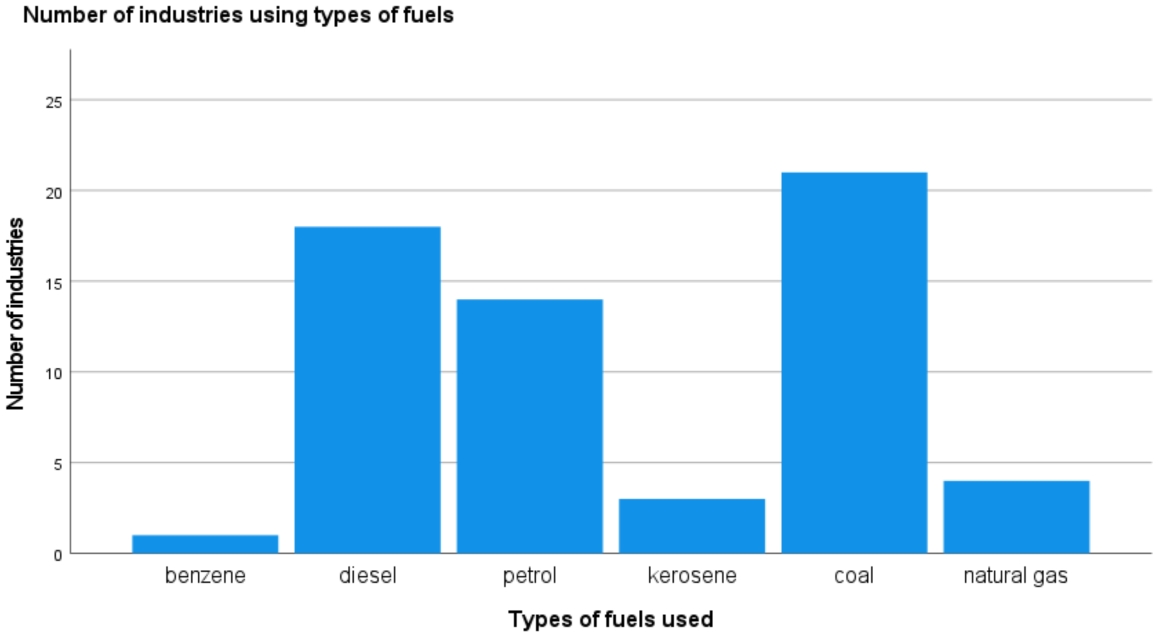

Figure 10: Types of fuels used in manufacturing industries

All industries selected coal as a fuel used, as seen in Figure 10. However, this is due to the fact that Eswatini uses coal for electricity. Coal mined in the country is anthracite, which is then exported to South Africa. The electricity Eswatini imports from South Africa is from bituminous coal (*National Energy Policy*, n.d.). Coal is one of the most carbon-intensive fuels and a major source of global GHG emissions due to its widespread use in electricity generation and industrial processes (Jijai et al., 2024; Zuiderveen et al., 2024). Coal primarily consists of carbon with some hydrogen, sulphur and other impurities. Burning coal emits more carbon dioxide per unit of energy than any other fossil fuel—approximately 0.93 kg per kWh for hard coal (H. Xu et al., 2022). Coal mining releases methane trapped in coal seams (coalbed methane), which has a high global warming potential. Though not a greenhouse gas, sulphur dioxide contributes to acid rain and can have indirect climate effects by forming aerosols (Lejda et al., 2021). Coal's high carbon content makes it the largest single contributor to global GHG emissions among fossil fuels.

Benzene is a hydrocarbon commonly found in crude oil and is a component of gasoline (Lao et al., 2021). While it is not typically used as a primary fuel, its combustion contributes to GHG emissions. Carbon dioxide and water vapour are the products of the reaction between benzene and oxygen during combustion. One of the main greenhouse gases, carbon dioxide, is released in considerable quantities when benzene is completely burned. If combustion is incomplete due to insufficient oxygen, it can produce carbon monoxide and unburned hydrocarbons (Abdollahnejad et al., 2015), which can indirectly contribute to warming. During the production and refining of benzene-containing fuels like gasoline, methane leaks can occur. Benzene also contributes indirectly to GHG emissions as part of gasoline blends. Its presence in vehicle exhaust can lead to the formation of ground-level ozone, a short-lived but potent greenhouse gas (Misra et al., 2023).

Diesel fuel was selected by approximately 86% of the respondents, mainly as the fuel used in distribution trucks. It is derived from crude oil and is more energy-dense than petrol but emits higher levels of certain pollutants (Lao et al., 2021). Diesel engines operate through compression ignition, where the fuel reacts with oxygen to produce energy along with carbon dioxide and water. Diesel combustion produces about 2.68 kg of carbon dioxide per liter burned (Collier et al., 2019; Su et al., n.d.). Diesel engines emit nitrous oxide gases, which contribute indirectly to global warming by promoting ozone formation. Incomplete combustion produces particulate matter like black carbon, which absorbs sunlight and has a warming effect many times stronger than carbon dioxide (Su et al., n.d.). Diesel engines are generally more efficient than petrol engines, which slightly reduces their carbon dioxide emissions per kilometres travelled. However, their higher nitrous oxide and particulate emissions offset these benefits (Thanatrakolsri & Sirithian, 2024).

Petrol is one of the most widely used fuels globally, especially in passenger vehicles. It is composed of hydrocarbons that release energy upon combustion. Similar to diesel, petrol combusts with oxygen to produce carbon dioxide and water (B. Xu & Lin, 2016). Petrol emits approximately 2.31 kg of carbon dioxide per liter burned. Small amounts of methane and nitrous oxides are also released during combustion (Gazda-Grzywacz et al., 2019; B. Xu & Lin, 2016). Petrol evaporation and incomplete combustion release volatile organic compounds, which contribute to ozone formation (Thanatrakolsri & Sirithian, 2024).

Kerosene is a middle distillate fuel commonly used for heating, lighting, and aviation. Its combustion also contributes to GHG emissions (DiGiulio et al., 2023). Kerosene burns similarly to other hydrocarbons and emits around 2.52 kg of carbon dioxide per liter burned (Turnbull et al., 2011). Although only 3 industries selected it as part of the fuels they use, it still emits greenhouse gases.

Natural gas is primarily composed of methane and is considered cleaner than coal or oil due to its lower carbon dioxide emissions during combustion (DiGiulio et al., 2023). When burned, methane reacts with oxygen to produce carbon dioxide and water (Li, Wang, et al., 2021). For every unit of energy produced, natural gas emits roughly half as much carbon dioxide as coal. Because methane has a 25-fold greater warming potential than carbon dioxide, its lower combustion emissions are greatly offset by methane leakage during extraction, transportation, and storage. (Zhou et al., 2024). Natural gas is often promoted as a "bridge fuel" for transitioning away from coal; however, addressing methane leaks is critical for realizing its climate benefit (Rasbash et al., 2023).

Table 2: Energy used annually in manufacturing industries

Energy used annually in MtCO2eq

Energy in MtCO2eq		Frequency	Percent	Valid Percent	Cumulative Percent
	188	1	4.8	9.1	9.1
	800	1	4.8	9.1	18.2
	1354	1	4.8	9.1	27.3
	1700	1	4.8	9.1	36.4
	2050	1	4.8	9.1	45.5
	2161	1	4.8	9.1	54.5
	2585	1	4.8	9.1	63.6
	2800	1	4.8	9.1	72.7
	3003	1	4.8	9.1	81.8
	3012	1	4.8	9.1	90.9
	3128	1	4.8	9.1	100.0
	Total	11	52.4	100.0	
Missing in	System	10	47.6		
Total		21	100.0		

Table 2 shows the energy used annually in the different manufacturing industries. Only 11 industries keep track and document their energy use. The other 10 does not quantify their energy use. The energies given were converted into million metric tons of carbon dioxide equivalent. A high energy quantity measured in $MtCO_2eq$ indicates a significant contribution to GHG emissions (Li, Xue, et al., 2021). This metric is used to standardize the warming potential of different GHGs like carbon dioxide, methane and nitrous oxide, into a single unit based on their global warming potential (GWP). The implications of such high emissions are far-reaching, affecting the environment, economy, public health, and global climate systems (Hofny et al., 2024; Kosai et al., 2022).

4.3 Assessing mitigation measures used by manufacturing industries

The second objective for this study was to identify and assess any climate change mitigation measures that the manufacturing industries in Matsapha Industrial area used, if any. All the industry representatives have heard of climate change. However, not all of the industries have a system in place for tracking greenhouse gas emissions. A majority of the manufacturing industries do have a tracking system in place, with 57%. Approximately 38% and 5% do not have tracking systems and / or are unsure respectively.

A Pearson's correlation 2-tailed test was done between familiarity about climate change and a system for tracking greenhouse gas emissions. A moderate, positive relationship between the two variables was a result, with 0.538 correlation. That means, the more an industry representative is familiar with climate change, the more chances that industry will have a system in place for tracking greenhouse gas emissions. The findings suggest that increasing education and awareness about climate change may encourage more manufacturing industries to implement tracking systems for GHG emissions, but it is not the sole determining factor. Other influences should also be considered in decision-making and policy development.

In addition to knowing about climate change, and having a GHG emission tracking system in place, there are energy efficiency measures that manufacturing industries use. The main purpose of using these measures however, is to save on monetary costs associated with electricity usage. Nonetheless, these measures also pour into reduction of greenhouse gas emissions. Upgrading equipment and machinery in manufacturing industries significantly enhances energy efficiency, which directly contributes to the reduction of greenhouse gas (GHG) emissions (DiGiulio et al., 2023). Approximately 91% of the manufacturing industries selected the equipment and machinery upgrade measure. This energy efficiency measure has various benefits that eventually feed into reduction of greenhouse gas emissions. Modern manufacturing equipment is designed to consume less energy while maintaining or improving productivity (Zuiderveen et al., 2024). For example, high-efficiency motors and compressors use advanced designs and materials to minimize energy waste (Yousefi et al., 2021; Zuiderveen et al., 2024). By lowering energy demand, manufacturers reduce reliance on fossil-fuel-based electricity, which is a major source of GHG emissions. Energy-efficient machinery often has longer lifespans due to better design and materials (Jijai et al., 2024). This reduces the frequency of replacements, lowering the emissions associated with manufacturing and transporting new equipment. 95% chose optimising production processes as an energy efficiency measure. Optimizing production processes in manufacturing industries enhances energy efficiency and reduces GHG emissions by streamlining operations, minimizing waste, and improving resource utilization (Lejda et al., 2021). Process optimization identifies inefficiencies in manufacturing workflows, such as idle machinery, excessive heating or cooling, and unnecessary energy usage (Zhou et al., 2024). By addressing these inefficiencies, energy consumption per unit of output decreases, which directly lowers GHG emissions associated with electricity or fuel use. For example, synchronizing heating and cooling systems with production schedules ensures energy is only used when needed (DiGiulio et al., 2023; Li, Wang, et al., 2021).

From the transport department, as this forms a large part of manufacturing industries for distribution, there are GHG emission reduction strategies that these industries can use. 16 of the manufacturing industries do route optimization as seen in figure 10. Route optimization in manufacturing industries plays a significant role in reducing GHG emissions by improving the efficiency of logistics and transportation processes. Optimizing routes minimizes the distance travelled by vehicles, which directly lowers fuel usage (Turnbull et al., 2011). By selecting the most efficient paths, manufacturers can avoid unnecessary detours and reduce mileage which can save up to 20% on fuel costs (Abdollahnejad et al., 2015). This reduction in fuel consumption translates to fewer emissions from fossil-fuel-powered vehicles.

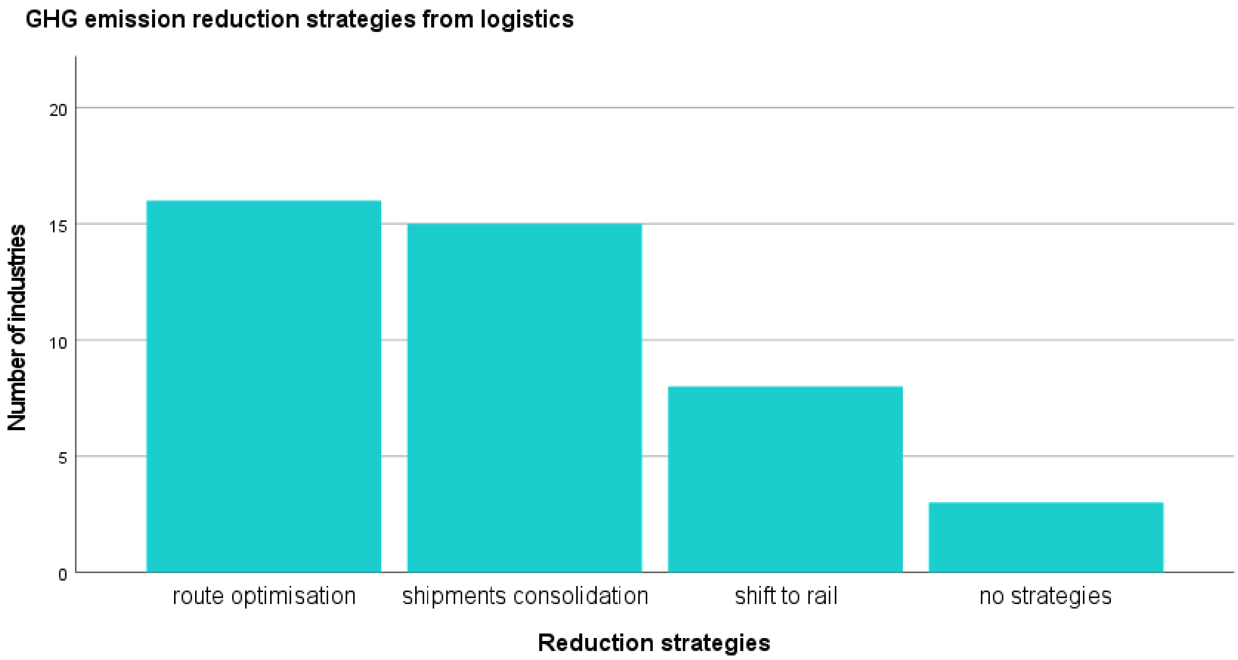

Figure 11: GHG emission reduction strategies from logistics

With only 8 of the manufacturing industries using rail in addition to road transport, it is a significant GHG emission reduction strategy. Rail freight emits only 1.99 g of carbon dioxide per tonne-km compared to 46.9 g of carbon dioxide per tonne-km for road transport (Lao et al., 2021; Zhou et al., 2024). Moving goods by rail instead of trucks reduces GHG emissions by up to 75% on average (Collier et al., 2019). Railways are inherently more energy-efficient due to their ability to carry large volumes of passengers or freight (Thanatrakolsri & Sirithian, 2024). Therefore, shifting from road to rail for goods distribution and transport is a key strategy for reducing emissions and achieving climate goals.

4.4 Assessing industrial dogma

The third objective for this study was to identify and assess policies that govern the industrial sector, if any. According to the Ministry of Tourism and Environmental Affairs, which is the designated climate change ministry of Eswatini, there are no policies that govern strictly the manufacturing industries. Eswatini has various climate change and sustainability policies. These are;

Table 3: Eswatinis' climate change and sustainability policies

Short term (0 – 3 years)	**Medium term (3 – 5 years)**	**Long term (more than 5 years)**
National Development Plan (NDP) 2023/24 – 2027/38 Multi hazard contingency Plan (yearly)	National Climate Change Strategy and Action Plan (NCCSAP) (2015-2020) The Kingdom of Eswatini Strategic Roadmap 2019-2023 Ministries Action Plans to 2018 and 2022 National Emergency Response, Mitigation and Adaptation Plan (NERMAP 2016-2022)	National Food and Nutrition Policy 2016 Eswatini National Agriculture Investment Plan under the Comprehensive African Agricultural Development Programme (CAADP) to 2025 Climate Smart Agriculture Policy, 2019 National Agriculture Investment Plan 2015-2025 Irrigation Policy of 2005 Disaster Management Act, 2006 National Disaster Risk Management Policy, 2011 National Emergency Response Mitigation and Adaptation Plan (NERMAP 2016-2022) Water Resilience Strategy 2017 National Water Supply and Sanitation Master Plan 2020 (under development) Water Policy 2019 National Environment Policy 1999 National Biosafety Policy 2009 National Solid Waste Management Strategy 2000 Environment Management Act 2002 National Strategy for the Control and Management of Invasive Alien Plant Species: 2020 – 2030

		The Environmental Assessment, Audit and Review Regulations, 2000 The Waste Regulations, 2000 The Ozone Depleting Substances Regulations, 2003 National Biodiversity Conservation and Management Policy 2007 Forest Policy, 2001 National Biodiversity Strategy and Action Plan 2016 Air Pollution Control Regulations 2010 Water Pollution Control Regulations 2010 Litter Regulations 2012 The Flora Protection Act 2001 The Eswatini National Trust Commission Act of 1972 Air Pollution Regulations 2010 Kingdom of Eswatini Energy Masterplan 2018-2034 National Biofuels Strategy and Action Plan (NBSAP) 2009 National Energy Policy 2018 National Energy Policy Implementation Strategy 2009 Programme Framework for Affordable Renewable Energy in Eswatini (PARES) 2018 Short term generation plan for energy 2018

		Eswatini Independent Power Producer Policy 2015 Energy Efficiency and Conservation Policy 2019

Climate change is a serious matter to the countrys' government. A climate change bill is currently being reviewed, with the end goal of enacting it into an Act. In 2010, the government formed a multi-stakeholder National Climate Change Committee (NCCC) to guarantee efficient coordination of climate change across sectors. Members of the NCCC come from academia, the private sector, civil society organisations, and government ministries and departments. In order to direct the nation's climate change initiatives, the NCCC is in charge of communicating and working with other pertinent stakeholders (THE KINGDOM OF SWAZILAND MINISTRY OF TOURISM AND ENVIRONMENTAL AFFAIRS NATIONAL CLIMATE CHANGE POLICY, 2016, n.d.-b).

At the industry level, only 59% of the employees selected yes to the question of their company having policies aimed at reducing their environmental impacts. From the industry representative side, 43% replied positively to their industries having climate change mitigation policy or plan with defined targets, 19% has the policy but not with defined targets, 24% does not have a climate change mitigation policy or plan, but plans to develop one, and 14% does not have it at all.

4.5 Assessing climate change knowledge among industrial stakeholders

Measuring climate change awareness is important. It helps researchers, governments, and organizations gauge how much people know about climate change, its causes, and its impacts. Knowing whether people believe climate change is real, human-caused, or urgent helps shape effective messaging and actions (Suresh et al., 2018). As a result, if awareness is low, education campaigns might be a priority. If awareness is high, the focus might shift to encouraging action. Decision-makers can develop targeted interventions suited to specific communities or regions based on awareness levels (Özbek et al., 2023). Assessing awareness must also be continuous. Measuring awareness at regular intervals helps track whether public understanding is improving, staying the same, or declining (Żółtowski & Grzelak, 2016). It helps evaluate whether past education efforts, media campaigns, or policies have been effective.

For this study, questionnaires were administered to industry employees for the purposes of gauging their climate change awareness. Approximately 67% of employees from the 21 manufacturing industries, have never received any climate change training of any kind. However, 89% have heard of climate change, but it is at surface level. When asked to select how they define climate change, they answered as follows;

- 44.4% - rising global temperature
- 33.3% - changes in weather patterns
- 22.2% - increased frequency of extreme weather events
- 0% - melting polar ice caps

It is evident that none of the employees' associate climate change with melting polar ice caps. That can be explained with the location of Eswatini, being a landlocked country (Mavimbela et al., 2021). Compared to the residents, approximately 11% selected melting ice caps as a definition of climate change. This can be explained by the sample size between the two populations, with employees having 63 respondents whilst residents had 385 respondents. The respondent pool for the latter was broad. However, 95.3% of residents selected rising temperatures as a definition of climate change, which can be assumed as the general view for residents and employees around Matsapha Industrial Area.

All employees were of the idea that manufacturing industries have a role to playing in causing climate change. When asked what they think are the causes of climate change, the results were as follows;

- Industrial activity – 27.9%
- Deforestation – 30.2%
- Fossil fuel – 32%
- Natural – 9.9%

In general, employees, although having received little to no formal training on climate change, are somewhat knowledgeable on what climate change is and its' causes. It is increasingly important for industrial employees to have knowledge of climate change due to its direct and indirect impacts on workplaces, workforce health, and the broader economy. Workers need to understand climate change risks to adopt safe practices and mitigate potential health impacts. Rising temperatures, extreme weather events, and other climate-related disruptions can reduce workforce productivity (Wyssusek et al., 2022). Climate awareness enables employees to adapt their workflows, use protective measures, and maintain productivity in changing conditions. As industries transition toward sustainability and green technologies, employees without climate literacy may face challenges in adapting to new roles or technologies. Climate knowledge is becoming a key skill for employability in the emerging green economy, much like digital literacy was in the past (Fathi et al., 2021). Employees who understand climate issues are better positioned to contribute to sustainable practices within their organizations and advance their careers.

It is equally important for residents to be aware of climate change issues. Approximately 39% of residents are of the idea that climate change is caused by human activity, and approximately 4.9% agrees with climate change occurring naturally, as seen in figure 11.

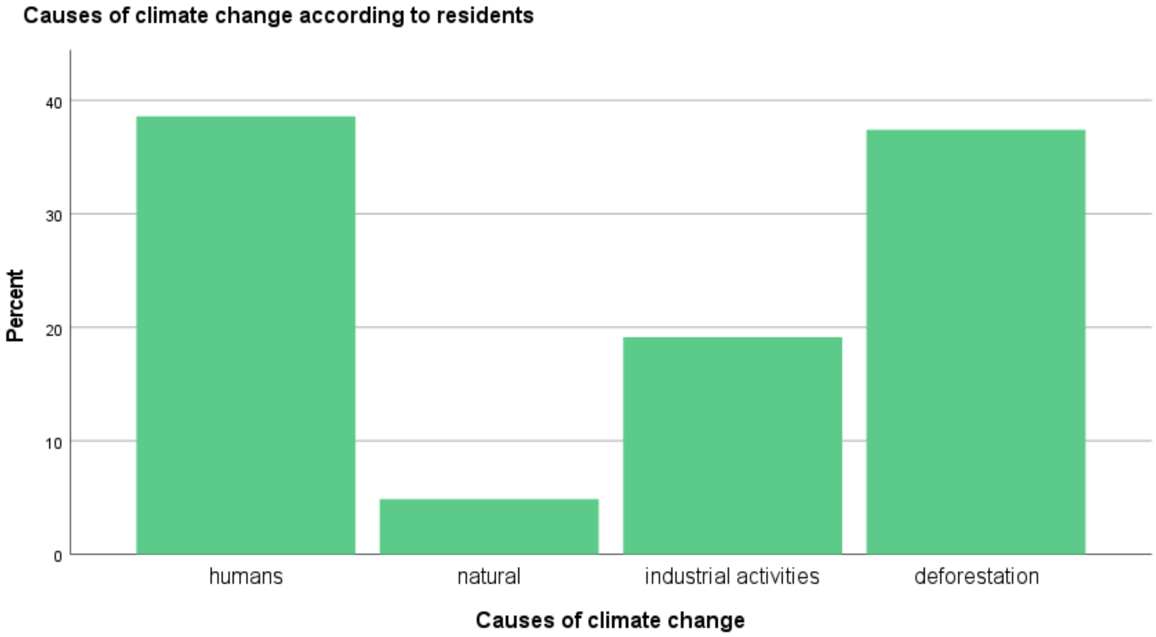

Figure 12: Causes of climate change according to residents

Furthermore, residents were asked if they had noticed any environmental changes in their area of residence that could be linked to manufacturing industries. Their responses can be grouped into the following;

- Frequent wild fires
- Frequent storms and hailstorms
- Flooding
- Heavy rains

- Changes in weather patterns
- Changes in temperature
- Air pollution
- Smoke around the industrial site
- River pollution
- Fish dying
- Waste generation affecting aesthetics

Chapter 4 has presented a comprehensive analysis and discussion of the study's findings, structured according to the specific objectives outlined in earlier chapters. The results, supported by tables and graphical representations, highlight key insights, including the highest and lowest values observed in the data. These findings effectively address the research questions, demonstrating alignment with the study's purpose and conceptual framework. Furthermore, the chapter underscores the significance of the methodology employed and provides a clear narrative connecting the results to relevant literature.

5. CONCLUSION AND POLICY RECOMMENDATIONS

5.1 Overview

This final chapter presents a comprehensive synthesis of the study's findings on the assessment of mitigation measures adopted by manufacturing industries. It seeks to connect the research outcomes to practical and actionable insights that can guide policymakers, industry leaders, and regulatory bodies in enhancing the effectiveness of mitigation strategies across the manufacturing sector.

The chapter begins with a summary reflection on the overall research objectives and the extent to which they have been achieved. It revisits the core findings, emphasizing their relevance to the evolving challenges faced by manufacturing industries.

The chapter concludes with outlining the policy recommendations derived from the study. These policy insights emphasize the importance of creating an enabling environment where industries adopt proactive and innovative mitigation measures. It presents targeted recommendations tailored to key stakeholders, including government agencies, industry associations, and individual manufacturing companies. These recommendations focus on strengthening existing mitigation frameworks, encouraging the adoption of advanced technologies, enhancing monitoring and enforcement mechanisms, and fostering a culture of continuous improvement in safety, environmental performance, and risk management.

5.2 Conclusion

The manufacturing sector, a cornerstone of global economic activity, and of Eswatini, is both a significant contributor to greenhouse gas emissions and a critical arena for climate change mitigation efforts. As the impacts of climate change intensify, including rising temperatures and extreme weather events, the urgency to decarbonize this sector has become paramount. However, the complexity of manufacturing processes, coupled with the sector's reliance on fossil fuels, presents unique challenges that demand innovative and comprehensive strategies. Efforts to mitigate climate change in the manufacturing sector have gained momentum in recent years, with a growing emphasis on policies, technologies, and circular economy practices. Despite these advances, the sector's decarbonization trajectory remains insufficient to meet the targets of the Paris Agreement, underscoring the need for more robust interventions.

The literature reveals persistent gaps and challenges in the implementation of climate change mitigation strategies within manufacturing industries. First, there is a lack of alignment between policy frameworks and the technological needs of the sector. While policies such as carbon pricing and subsidies for renewable energy adoption have shown promise, their effectiveness is often constrained by inconsistent enforcement and insufficient incentives for innovation. For this study area in particular, all manufacturing industries do not know about carbon market. This is an obvious information gap area that needs to be filled. Second, the sector faces significant barriers to adopting low-carbon technologies, including high upfront costs, limited access to financing, and the risk of stranded assets. Furthermore, the integration of circular economy practices, while promising, requires systemic changes in supply chains and consumer behavior, which are often met with resistance.

In conclusion, the manufacturing sector's transition to a low-carbon future is both a necessity and an opportunity. By addressing the identified gaps and leveraging the potential of innovative policies and technologies, this research aims to contribute to the global effort to combat climate change while fostering sustainable industrial growth.

5.3 Policy Recommendations

The manufacturing sector is a significant contributor to GHG emissions globally, and in Eswatini, it represents the largest source of emissions (THE KINGDOM OF SWAZILAND MINISTRY OF TOURISM AND ENVIRONMENTAL AFFAIRS NATIONAL CLIMATE CHANGE POLICY, 2016, n.d.-b). To address this, comprehensive policies are needed at both the organizational and national levels to mitigate climate change.

Accurate tracking of GHG emissions is foundational for identifying emission hotspots and implementing targeted reductions. Without robust tracking systems, industries cannot effectively measure their environmental impact or comply with future regulations. Implementation of automated systems to ensure accurate, real-time data collection across manufacturing industries is recommended. With more than half of the manufacturing industries in Matsapha Industrial Area having a GHG tracking system, it is already on ground and understood. What is left now is upscaling it, and legalizing the necessity of the system.

Industries can be equipped with sensors and emissions management software, such as Persefoni (Zuiderveen et al., 2024), to monitor emissions from energy use, production processes, and transportation. Having these tracking systems will improve compliance with global standards, assist Eswatini in reporting on GHG emissions, enhance operational efficiency and enable better access to international markets.

Another recommendation at industry level is the education and training of employees on climate change and its' issues. Employees are critical change agents in achieving sustainability goals. Climate literacy equips them with the knowledge and skills needed to take informed actions that reduce emissions.

On the national scale, national policies are vital as they provide a framework for industries to align their operations with climate goals. In Eswatini, where manufacturing is the largest emitter of GHGs (THE KINGDOM OF SWAZILAND MINISTRY OF TOURISM AND ENVIRONMENTAL AFFAIRS NATIONAL CLIMATE CHANGE POLICY, 2016, n.d.-b), such policies are essential for achieving meaningful reductions. A recommendation would be to develop a comprehensive plan that includes adaptation, mitigation, and prevention strategies. This plan should focus on energy efficiency, cleaner production technologies, and waste reduction in the manufacturing industry. Government should also mandate GHG reporting and require all manufacturing entities to report their emissions annually. This data can inform national climate strategies and ensure accountability. It can also assist in the compilation of more ambitious NDC documents by reporting on accurate data.

Moreover, climate change mitigation requires coordinated efforts between governments, industries, and civil society. The importance of private public partnerships cannot be overemphasized. Government should foster collaborations between government agencies and private companies to fund research into low-carbon technologies. Eswatini should also work with neighboring countries to share best practices and resources for industrial decarbonization. Current regulations are insufficient to address the urgency of climate change. This is not only for the manufacturing sector, but for all sectors in Eswatini that are identified as GHG emitters. Acts and policies need to be updated to include climate change mitigation and adaptation. An in-depth research is needed for detailing the types and distribution of manufacturing industries across Eswatini, not just the ones found in Matsapha

Industrial area. This will enable policymakers to tailor climate policies to the types found in the country, thereby enhancing adoption.

Furthermore, creation of policies is not enough for effectiveness. There needs to be a clear monitoring, reporting and verification of any strategies and action plans created for such. It ensures transparency, accountability and accurate tracking of emissions reductions and policy impacts. This will also enhance data collection phases whenever the NDC is supposed to be submitted to the UNFCCC.

We cannot stray from the fact that in production, there will be waste. It is important for government to develop programs to capture and utilize methane emissions from landfills. Eswatini has not completely moved from using landfills, thus this recommendation. Methane recovery is a cost-effective way to reduce GHG emissions. On the other hand, renewable energy really needs to be scaled up in Eswatini. The country needs to be energy secure, as it is currently importing electricity from South Africa. On the quest to being energy secure, the country needs to invest on renewable energy such as solar. This will reduce dependence on fossil fuels, whilst protecting the country from political instability that may threaten our power availability from other countries.

These recommendations aim to create a sustainable industrial framework that balances economic growth with environmental responsibility, contributing to long-term climate resilience.

6. APPENDICES

6.1 Questionnaire for industries

QUESTIONNAIRE FOR MANUFACTURING INDUSTRIES ON CLIMATE CHANGE MITIGATION STRATEGIES

This questionnaire aims to gather comprehensive information from manufacturing industries regarding their emissions, mitigation measures and compliance.

Part one: Background information

1. Name of industry:
2. Date of establishment:
3. Number of employees:
4. Position of representative:
5. Education level of representative
   - ☐ High school
   - ☐ Undergraduate
   - ☐ Post graduate
6. Type of manufacturing industry
   - ☐ Automotive
   - ☐ Textile and apparel
   - ☐ Food and beverage
   - ☐ Chemical
   - ☐ Other (please specify) ________________________

Part two: General Awareness and Emissions Knowledge

7. How familiar are you with your company's greenhouse gas emissions sources?
   - ☐ Very familiar
   - ☐ Somewhat familiar
   - ☐ Neutral
   - ☐ Slightly familiar
   - ☐ Not familiar at all

8. Does your company have a system in place to track and report greenhouse gas emissions?
   - ☐ Yes
   - ☐ No
   - ☐ Unsure

9. How important do you consider reducing GHG emissions for your business?
   - ☐ Very important
   - ☐ Moderately important
   - ☐ Slightly important
   - ☐ Not important

Part three: Emissions Sources and Energy Use

10. Which of the following are the primary sources of GHG emissions in your operations? (Select all that apply)
    - ☐ Direct fuel combustion (e.g., boilers, furnaces)
    - ☐ Electricity usage
    - ☐ Industrial processes (e.g., chemical reactions, metallurgical processes)
    - ☐ Transportation (e.g., company vehicles, product shipping)
    - ☐ Waste management and disposal
    - ☐ Other (Please specify): ________

11. What type of fuel do you use? (select all that apply)
    - ☐ Benzene
    - ☐ Diesel
    - ☐ Petrol
    - ☐ Kerosene
    - ☐ Coal
    - ☐ Natural gas
    - ☐ Other (Please specify) __________________________

12. What percentage of your company's total energy use comes from fossil fuels?
    - ☐ 0-25%
    - ☐ 26-50%
    - ☐ 51-75%
    - ☐ 76-100%
    - ☐ Unsure

13. What percentage of your company's total energy use comes from renewable sources?
    - ☐ 0-25%
    - ☐ 26-50%
    - ☐ 51-75%
    - ☐ 76-100%
    - ☐ Unsure

14. Which energy efficiency measures has your company implemented to reduce GHG emissions? (Select all that apply)
    - ☐ Equipment and machinery upgrades
    - ☐ Optimizing production processes
    - ☐ Energy-efficient lighting and building improvements
    - ☐ Energy recovery systems (e.g., waste heat recovery)
    - ☐ None currently in place
    - ☐ Other (please specify): ________

Part four: Waste Management and Emissions

15. What type of waste does your company produce? (Select all that apply)
    - ☐ Organic waste

- ☐ Hazardous waste
- ☐ Plastic waste
- ☐ Glass waste
- ☐ Electronic waste
- ☐ Other (Please specify) ____________________________

16. How does your company handle industrial waste and by-products? (Select all that apply)
    - ☐ Recycling or repurposing materials
    - ☐ Waste-to-energy conversion
    - ☐ Landfill disposal
    - ☐ Hazardous waste treatment and disposal (incineration)
    - ☐ On-site composting
    - ☐ Other (please specify): __________________

17. What is the height of the chimney used if any of your waste is incinerated?
    - ☐ Less than 20m
    - ☐ More than 20m
    - ☐ Unsure

18. To what extent do you believe waste management practices in your company contribute to GHG emissions?
    - ☐ Major contributor
    - ☐ Moderate contributor
    - ☐ Minor contributor
    - ☐ No contribution

19. Does your company actively work to reduce emissions associated with waste?
    - ☐ Yes
    - ☐ No
    - ☐ Unsure

Part five: Supply Chain and Logistics

20. Does your company consider GHG emissions when choosing suppliers and logistics partners?
    - ☐ Always
    - ☐ Sometimes
    - ☐ Rarely
    - ☐ Never
    - ☐ Unsure

21. What region(s) does your company operate in? (Select all that apply)
    - ☐ North America
    - ☐ South America
    - ☐ Europe
    - ☐ Asia

- ☐ Africa

22. What transportation modes does your company primarily use for product distribution? (Select all that apply)
    - ☐ Road
    - ☐ Rail
    - ☐ Air
    - ☐ Sea
    - ☐ Other (please specify): _______________

23. Have you implemented strategies to reduce emissions from logistics? (Select all that apply)
    - ☐ Route optimization
    - ☐ Use of low-emission vehicles
    - ☐ Consolidation of shipments
    - ☐ Shift to rail or other lower-emission transport modes
    - ☐ No strategies currently in place
    - ☐ Other (please specify): ________

Part six: GHG Reduction Strategies and Goals

24. Does your company have targets to increase renewable energy usage?
    - ☐ Yes, with a specific target percentage
    - ☐ Yes, but without a specific target
    - ☐ No, but considering it
    - ☐ No target currently in place

25. Does your company have a climate change mitigation policy or plan?
    - ☐ Yes, with defined targets and goals
    - ☐ Yes, but without defined targets
    - ☐ No, but planning to develop one
    - ☐ No policy or plan currently

26. What GHG reduction strategies has your company implemented? (Select all that apply)
    - ☐ Energy efficiency improvements
    - ☐ Renewable energy adoption
    - ☐ Carbon offset purchases
    - ☐ Process and equipment optimization
    - ☐ Sustainable sourcing and supply chain initiatives
    - ☐ None currently in place
    - ☐ Other (please specify): __________________

27. What barriers does your company face in reducing GHG emissions?
    - ☐ Cost of implementation
    - ☐ Lack of technical expertise
    - ☐ Lack of government incentives or policies

- ☐ Operational limitations
- ☐ Other (please specify): ___________________

28. Has your company conducted a climate risk assessment to identify potential climate-related impacts?
    - ☐ Yes, regularly
    - ☐ Yes, but infrequently
    - ☐ No, but planning to conduct one
    - ☐ No assessment conducted

29. What adaptation measures has your company taken to prepare for climate-related risks? (Select all that apply)
    - ☐ Infrastructure improvements (e.g., flood defenses, cooling systems)
    - ☐ Supply chain diversification
    - ☐ Emergency response planning
    - ☐ Insurance and financial planning for climate impacts
    - ☐ No specific adaptation measures taken
    - ☐ Other (please specify): ________

Part seven: Future Actions and Support

30. Would you be interested in tools or resources to help measure and reduce your company's GHG emissions?
    - ☐ Yes
    - ☐ No
    - ☐ Unsure

31. Which of the following areas would you like more information or resources on? (Select all that apply)
    - ☐ GHG emissions measurement and reporting
    - ☐ Energy efficiency technologies
    - ☐ Renewable energy options
    - ☐ Waste management best practices
    - ☐ Sustainable transportation and logistics
    - ☐ Carbon offset programs
    - ☐ Other (please specify): _________________

32. What are your company's priorities for the next 3-5 years regarding climate change mitigation?
    - ☐ Increase renewable energy use
    - ☐ Enhance energy efficiency
    - ☐ Improve waste reduction and recycling
    - ☐ Implement circular economy practices
    - ☐ Reduce transportation and logistics emissions
    - ☐ Other (please specify): __________________

33. Please share any additional comments or insights regarding your company's role in reducing GHG emissions:
____
____
____
____
____
____
____

34. How much energy does your company use per year?
____

Thank you for filling out this questionnaire!

6.2 Questionnaire for industry employees

QUESTIONNAIRE FOR INDUSTRY STAKEHOLDERS ON CLIMATE CHANGE INDUSTRY EMPLOYEES

Here is a questionnaire designed to assess climate change knowledge among industry stakeholders, mainly industrial employees. This includes questions on general awareness, perceived risks, and understanding of industry-specific impacts and mitigation strategies.

Section 1: Demographic Information
1. What is your age group?
   - [ ] 18–30
   - [ ] 31–50
   - [ ] 51–65
   - [ ] Over 65

2. What is your gender?
   - [ ] Male
   - [ ] Female

3. What is your role within the manufacturing industry?
   - [ ] Operations/Production
   - [ ] Maintenance/Technical
   - [ ] Quality Control
   - [ ] Management/Administrative
   - [ ] Other: ______________

4. How long have you been working in the manufacturing industry?
   - [ ] Less than 1 year
   - [ ] 1–5 years
   - [ ] 6–10 years
   - [ ] More than 10 years

5. What is your highest level of education?

- [ ] High school
- [ ] Technical/vocational training
- [ ] College
- [ ] University

Section 2: Awareness of Climate Change

6. Have you heard of the term "climate change"?
- [ ] Yes
- [ ] No

7. How would you define climate change?
- [ ] Rising global temperatures
- [ ] Changes in weather patterns
- [ ] Melting polar ice caps
- [ ] Increased frequency of extreme weather events
- [ ] Other: ______________

8. What do you think are the primary causes of climate change? (Select all that apply)
- [ ] Industrial activities
- [ ] Deforestation
- [ ] Fossil fuel combustion
- [ ] Natural processes (e.g., volcanic eruptions)
- [ ] Other: ______________

Section 3: Manufacturing Industry's Role

9. Do you think manufacturing industries contribute to climate change?
- [ ] Yes
- [ ] No
- [ ] Not sure

10. Which activities in manufacturing do you think have the greatest impact on the environment? (Select all that apply)
- [ ] Energy consumption
- [ ] Emissions from production processes
- [ ] Waste generation
- [ ] Water usage and pollution
- [ ] Use of non-renewable resources
- [ ] Other: ______________

11. Does your company have policies or initiatives to reduce its environmental impact?
- [ ] Yes
- [ ] No
- [ ] Not sure

12. Are you aware of any environmental certifications or standards your company complies with (e.g., ISO 14001)?
- [ ] Yes
- [ ] No

Section 4: Personal Knowledge and Practices

13. How knowledgeable do you feel about climate change?
- [ ] Very knowledgeable
- [ ] Somewhat knowledgeable
- [ ] Not very knowledgeable
- [ ] Not knowledgeable at all

14. Have you received any training related to environmental sustainability or climate change in your workplace?
- [ ] Yes
- [ ] No

15. What actions do you personally take to reduce your environmental impact? (Select all that apply)
- [ ] Reducing energy consumption at work/home
- [ ] Recycling materials
- [ ] Advocating for eco-friendly practices at work
- [ ] Using sustainable transportation
- [ ] Other: ______________

Section 5: Perceptions and Suggestions
16. How important do you think it is for the manufacturing industry to address climate change?
- [ ] Very important
- [ ] Important
- [ ] Neutral
- [ ] Not important

17. In your opinion, what are the most effective ways the manufacturing industry can combat climate change? (Select all that apply)
- [ ] Transitioning to renewable energy sources
- [ ] Reducing waste and improving recycling practices
- [ ] Adopting energy-efficient technologies
- [ ] Complying with stricter environmental regulations
- [ ] Educating employees about sustainable practices
- [ ] Other: ______________

18. What support or resources would help you contribute to climate change mitigation efforts at your workplace?
- [ ] Training or workshops
- [ ] Access to eco-friendly tools or technologies
- [ ] Incentives for sustainable practices
- [ ] Clear communication on company policies
- [ ] Other: ______________

19. Would you like to participate in initiatives aimed at reducing your company's environmental impact?
- [ ] Yes
- [ ] No
- [ ] Maybe

Thank you for completing this questionnaire. Your responses are valuable in understanding and addressing the role of manufacturing industries in combating climate change.

6.3 Questionnaire for residents

QUESTIONNAIRE FOR INDUSTRY STAKEHOLDERS ON CLIMATE CHANGE RESIDENTS

Here is a questionnaire designed to assess climate change knowledge among industry stakeholders, mainly industrial residents. This includes questions on general awareness, perceived risks, and understanding of industry-specific impacts and mitigation strategies.

Section 1: Demographic Information

1. What is your age group?
   - [ ] 18–30
   - [ ] 31–50
   - [ ] 51–65
   - [ ] Over 65

2. What is your gender?
   - [ ] Male
   - [ ] Female

3. What is your highest level of education?
   - [ ] Primary school
   - [ ] Secondary school
   - [ ] High school
   - [ ] College
   - [ ] University

Section 2: Awareness of Climate Change

5. Have you heard of the term "climate change"?
   - [ ] Yes
   - [ ] No

6. What do you think climate change means? (Select all that apply)
   - [ ] Rising global temperatures
   - [ ] Changes in weather patterns
   - [ ] Melting polar ice caps
   - [ ] Increased frequency of extreme weather events
   - [ ] Other: ______________

7. What are the primary causes of climate change, in your opinion? (Select all that apply)

- [ ] Human activities like burning fossil fuels
- [ ] Natural processes like volcanic eruptions
- [ ] Industrial activities
- [ ] Deforestation
- [ ] Other: ______________

Section 3: Impact of Manufacturing Industries

8. Do you think manufacturing industries contribute to climate change?
   - [ ] Yes
   - [ ] No
   - [ ] Not sure

9. Which of the following industrial activities do you believe affect the climate? (Select all that apply)
   - [ ] Air pollution (e.g., emissions)
   - [ ] Water pollution
   - [ ] Deforestation for industrial use
   - [ ] Energy consumption
   - [ ] Other: ______________

10. Have you noticed any environmental changes in your area that could be linked to manufacturing industries?
   - [ ] Yes
   - [ ] No
   - [ ] Not sure

   If yes, please describe: _______________

Section 4: Personal Perception and Responsibility

11. Do you feel knowledgeable about the topic of climate change?
   - [ ] Very knowledgeable
   - [ ] Somewhat knowledgeable
   - [ ] Not very knowledgeable
   - [ ] Not knowledgeable at all

12. How important do you think it is for individuals to act against climate change?
   - [ ] Very important
   - [ ] Important
   - [ ] Neutral
   - [ ] Not important

13. What actions have you personally taken to reduce your environmental impact? (Select all that apply)
   - [ ] Recycling
   - [ ] Reducing energy use

- [ ] Using public transportation or carpooling
- [ ] Avoiding single-use plastics
- [ ] Other: _____________

Section 5: Suggestions for Improvement

14. What measures do you think manufacturing industries should take to address climate change? (Select all that apply)
- [ ] Use renewable energy sources
- [ ] Reduce greenhouse gas emissions
- [ ] Adopt eco-friendly technologies
- [ ] Improve waste management
- [ ] Other: _____________

15. Would you like to participate in community programs aimed at combating climate change?
- [ ] Yes
- [ ] No
- [ ] Maybe

16. What additional information or support would help you understand and address climate change?
- [ ] Workshops or seminars
- [ ] Educational materials
- [ ] Access to government programs or incentives
- [ ] Other: _____________

Thank you for taking the time to complete this questionnaire! Your input is valuable in understanding and addressing the challenges posed by climate change.

6.4 Questionnaire for ministry

QUESTIONNAIRE FOR MINISTRIES AND AGENCIES CONCERNED WITH MANUFACTURING INDUSTRIES ON CLIMATE CHANGE

This questionnaire is designed to assess climate change policies specifically targeting the manufacturing industry. This questionnaire focuses on policy effectiveness, coverage, enforcement, and areas where further development may be needed.

Part one: Policy Scope and Objectives

1. Which Ministry or Agency is respondee from?
   - ☐ Ministry of Tourism and Environmental Affairs
   - ☐ Eswatini Environment Authority

2. Position of respondee: ____

3. Does your ministry use specific climate change policies or regulations that apply solely to the manufacturing industry?

- ☐ Yes
- ☐ No
- ☐ Under development

4. What are the primary objectives of these policies? (Select all that apply)
   - ☐ Reducing greenhouse gas (GHG) emissions
   - ☐ Improving energy efficiency
   - ☐ Encouraging renewable energy adoption
   - ☐ Promoting circular economy practices
   - ☐ Reducing pollution and waste
   - ☐ Other (please specify): _________________

5. What types of manufacturing industries are specifically targeted by these policies? (Select all that apply)
   - ☐ Heavy manufacturing (e.g., steel, cement)
   - ☐ Chemical manufacturing
   - ☐ Electronics and technology
   - ☐ Automotive
   - ☐ Food and beverage
   - ☐ Textiles
   - ☐ Other (please specify): _______

Part two: Policy Components and Requirements

6. Which of the following components are included in these climate policies for manufacturing? (Select all that apply)
   - ☐ Emissions reduction targets
   - ☐ Energy efficiency standards
   - ☐ Renewable energy requirements
   - ☐ Pollution control measures
   - ☐ Waste management guidelines
   - ☐ Incentives for sustainable practices
   - ☐ Penalties for non-compliance
   - ☐ Other (please specify): _______

7. Do these policies require manufacturing companies to track and report their greenhouse gas emissions?
   - ☐ Yes, mandatory reporting
   - ☐ Yes, voluntary reporting
   - ☐ No reporting requirements

8. What timeframes or deadlines have been established for compliance with these policies?
   - ☐ Short-term (1-3 years)
   - ☐ Medium-term (3-5 years)
   - ☐ Long-term (5+ years)

- ☐ No specific timeframes

Part three: Policy Enforcement and Compliance

9. How are these climate policies for manufacturing enforced? (Select all that apply)
   - ☐ Regular inspections and audits
   - ☐ Mandatory reporting to the ministry
   - ☐ Penalties or fines for non-compliance
   - ☐ Third-party verification
   - ☐ Other (please specify): ___________________

10. How would you rate the level of compliance among manufacturing companies with these climate policies?
   - ☐ High compliance
   - ☐ Moderate compliance
   - ☐ Low compliance
   - ☐ Not monitored

11. What are the most common barriers to compliance reported by manufacturing companies? (Select all that apply)
   - ☐ High costs of compliance
   - ☐ Lack of technical expertise
   - ☐ Limited access to sustainable resources or technologies
   - ☐ Insufficient incentives
   - ☐ Complexity of regulatory requirements
   - ☐ Other (please specify): ________

Part four: Policy Effectiveness and Outcomes

12. What metrics or indicators does the ministry use to assess the effectiveness of climate policies for the manufacturing industry? (Select all that apply)
   - ☐ GHG emissions reduction
   - ☐ Energy consumption reductions
   - ☐ Renewable energy adoption rate
   - ☐ Pollution levels
   - ☐ Waste reduction and recycling rates
   - ☐ Other (please specify): _____________________

13. How effective do you believe these policies have been in achieving their intended climate goals?
   - ☐ Very effective
   - ☐ Moderately effective
   - ☐ Slightly effective
   - ☐ Not effective
   - ☐ Too early to assess

14. What positive outcomes have been observed in the manufacturing industry as a result of these policies? (Select all that apply)
   - ☐ Reduction in emissions and pollution

- ☐ Increased use of renewable energy
- ☐ Improved energy efficiency
- ☐ Adoption of waste reduction practices
- ☐ Increased innovation in sustainable manufacturing
- ☐ Other (please specify): ________

Part five: Policy Challenges and Improvement Areas

15. What are the main challenges the ministry faces in implementing and enforcing climate policies for the manufacturing industry? (Select all that apply)
    - ☐ Limited funding or resources
    - ☐ Lack of industry cooperation
    - ☐ Complexity in tracking and monitoring compliance
    - ☐ Insufficient technical expertise within the ministry
    - ☐ Insufficient incentives for companies
    - ☐ Other (please specify): ________________________

16. Which of the following areas do you believe require additional policy support or regulation? (Select all that apply)
    - ☐ Renewable energy integration
    - ☐ Emissions reduction targets
    - ☐ Sustainable waste management practices
    - ☐ Energy efficiency improvements
    - ☐ Circular economy initiatives
    - ☐ Research and development in low-carbon technologies
    - ☐ Other (please specify): _________________________

Part six: Future Policy Development and Support

17. What types of support or incentives are currently available to manufacturing companies to help them comply with climate policies? (Select all that apply)
    - ☐ Financial incentives (e.g., tax credits, grants)
    - ☐ Technical support and training
    - ☐ Access to sustainable technology and resources
    - ☐ Recognition and certification programs
    - ☐ No specific support or incentives
    - ☐ Other (please specify): ________

18. What additional support mechanisms would you recommend to enhance compliance and effectiveness of climate policies in manufacturing?
    ____
    ____
    ____
    ____
    ____

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