UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF SCIENCE, SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCES (APES)
MASTER'S IN ENVIRONMENTAL SCIENCES (APES7026A)

IMPLEMENTING RESOURCE EFFICIENT AND CLEANER PRODUCTION AS A TOOL TO REDUCE CARBON TAX IN THE MANUFACTURING INDUSTRIES

Phathutshedzo Ndifelani, Maggie Mashau

878251

A Research Report, submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Masters of Science.

October 2022, Johannesburg, South Africa

Declaration

I declare that this research report is my own, unaided work. It is being submitted for the Masters degree in Environmental Sciences at the University of the Witwatersrand, Johannesburg. Furthermore, I declare that this research report has not previously been submitted for any degree or examination at any other university. I fully acknowledge the rules of the University in this regard and will abide by the consequences of being in breach of the rules and regulations concerning plagiarism.

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Abstract

The carbon tax came into effect in South Africa in June 2019 to reduce greenhouse gas emissions (GHGs). With its first phase focusing on scope one carbon emissions, facilities that combust 10 megawatts or more became liable for a carbon tax. Among these are large emitting industries like manufacturing plants. This has placed a greater burden on industries under the current economic status, worsened by the COVID-19 pandemic. In addition to paying for the scope one tax liabilities, companies must report verified carbon emission and energy consumption patterns (energy plans), which require resources. Implementing resource-efficient and cleaner production (RECP) methodologies in industries have been the mandate of the National Cleaner Production Centre South Africa (NCPCSA), the programme of the national government, to reduce the environmental footprint and improve industry competitiveness. As a result, many industries in South Africa are focused on reducing their resource consumption and environmental footprint by improving efficiencies in production processes.

This research evaluated the benefit of the implementation of RECP as a tool to reduce carbon tax in manufacturing industries. Quantitative methods were applied in the data collection and analysis of three manufacturing plants that embarked on RECP implementation. Semi-structured interviews were also conducted with expert consultants and company managers who were part of the team for the RECP implementation facilitated by the NCPCSA. Quantitative data were collected during the RECP assessment and the case study phase of RECP implementation. Regression analyses were applied to determine the energy baseline for each plant for further evaluation of the RECP implementation results. The quantitative results of the RECP implementation have shown a reduction in energy consumption, equivalent carbon emissions, and associated costs including equivalent carbon tax savings in all three plants. The interview responses have shown that the perception of RECP expert consultants and company managers support that implementation of the RECP methodologies in industries provides the basis for measurement and verification of energy consumption and equivalent greenhouse gas emissions for reporting purposes as per legislative requirements. They also agreed that RECP is beneficial in reducing energy consumption, greenhouse gas emissions, and associated costs (resource costs and carbon tax). These reductions in GHG emissions and costs can reduce the manufacturing plants' carbon tax liabilities if the reduced carbon emissions fall under scope one in the current phase of carbon tax implementation (June 2019- December 2022). Nevertheless, the resulting reduction in energy consumption and equivalent carbon emissions were sufficient to draw some conclusions and recommendations.

Acknowledgment

First, I would like to thank my God for giving me strength and courage in writing this research paper. My sincere gratitude goes to my supervisor, Dr. Ute Schwaibold, for her effort and assistance throughout this research project. I would also like to extend thanks to the National Cleaner Production Centre South Africa (NCPCSA) for my experience in RECP implementation and for providing the platform to obtain the research data. Moreover, to the Expert consultant and the company managers for participating in this research interviews. Finally, yet importantly, to my family, for their support and encouragement.

List of Acronyms and Abbreviations

AECI: African Explosive and Chemical Industries

CDD: Cooling Degree Day

CDM: Clean Development Mechanism

CO_2: Carbon Dioxide

DEA: Department of Agriculture and Rural Development

DFFE: Department of Forestry, Fisheries, and Environment

ETF: Exchange Trade Funds

GHG: Greenhouse Gas Emissions

HDD: Heating Degree Day

HVAC: Heating, Ventilating, and Air Conditioner

kg/CO: Kilogram/ Carbon emission equivalent

kWh: Kilo-watts-hour

LED: Light-Emitting Diode

$MtCO_2$: Mega Tonnes Carbo Emission Equivalent

NCPC: National Cleaner Production Centre

NDC: Nationally Determined Contribution

R: Rand

RECP: Resource Efficient and Cleaner Production

SDG: Sustainable Development Goals

SEC: Specific Energy Consumption

TCA: Thermal Content Analysis

tCO: Tonnes Carbon emission equivalent

UNFCC: United Nations Framework for Climate Change

UNEP: United Nations Environment Programme

VSD: Variable-Speed Drive

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CHAPTER 1: ORIENTATION OF THE STUDY

1.1. Introduction

Although to some extent a natural process, climate change has been worsened by human and industrial activities, which are known to result in excessive greenhouse gas (GHG) emissions and enhance the greenhouse effect (Garidzirai, 2020). In the South African economy, coal in the energy and industry sector contributes 90% of the country's greenhouse gas emissions (Nuryartono and Rifai, 2017). Coal combustion generates approximately 91% of electricity in South Africa (Eskom, 2016). It results in carbon dioxide (CO2) emissions, which are the main greenhouse gas, making it the main contributor to greenhouse gas emissions, accounting for more than 85% (DEA, 2017). According to 2014 records, South Africa produced a total of equivalent 524 metric tons of carbon dioxide ($MtCO_{2e}$), making the country one of the top 14 global emitters (DEA, 2017).

These excessive carbon dioxide emissions causing global warming have become one of the greatest economic and environmental challenges worldwide (Garidzirai, 2020), causing climate change-related disasters like floods, fire, and drought. This has stimulated global discussions on climate change mitigation strategies, beginning with the Kyoto Protocol of 1997, where agreements with combined targets to reduce greenhouse gases between countries were initiated. At the United Nations Conference on Climate Change (UNFCCC) in March 2002, South Africa signed on to the Kyoto Protocol and committed to the legally binding international climate change treaty known as the Paris Agreement, which was approved in 2015 at the United Nations Conference of Parties (COP) on Climate Change. By 2020 and 2025, South Africa has pledged to cut greenhouse gas emissions by 42% and 34%, respectively. According to National Treasury (2010), the Intended Nationally Determined Contribution (INDC) plans were created as an efficient response to the goal of reducing greenhouse gas emissions.

The country's response to climate change policies has led the government to develop and implement mitigation measures as part of the INCD to reduce the impact of greenhouse gas emissions on climate change. This includes cleaner renewable energy sources, promoting energy efficiency strategies, carbon sequestration, clean development mechanisms (CDM), and carbon tax. The primary objective of the carbon tax that South Africa enacted in June 2019 is to sustainably reduce greenhouse gas emissions. This plays a crucial role in ensuring that South Africa achieves the domestic target outlined in the Nationally Determined Contribution (NDC), which was incorporated as South Africa's commitment to the Paris

Agreement of 2015 (National Treasury, 2019) as part of its contribution to the global effort to mitigate climate change. A carbon tax is designed to promote the ‘polluter pay’ principle for heavy industries that are significant emitters and helps ensure that industries consider the negative costs of their emissions in future production, consumption, and investment decisions (National Treasury 2019). However, these legislative developments have placed the burden on industries that produce direct GHG emissions to measure and report on their energy use patterns and GHG emissions based on the National GHG emission report regulation of the Department of Forestry, Fisheries, and Environment (DFFE), in addition to paying for their Scope 1 GHG emissions (Deloitte, 2019) in the first phase (from June 2019 to December 2022).

The manufacturing industry is one of the most carbon and resource-intensive sectors, which now presents a growing challenge from an environmental and economic perspective, as industries are now obliged to reduce their environmental footprint. The key factors for South African industries to improve sustainability are known to be backed up by increased growth, reduced operating costs, and improved environmental compliance, which also includes the reduction of greenhouse gas emissions. The global economic recession has also influenced the manufacturing industries to shift their focus to increasing production at minimal costs to stay afloat and competitive. The additional burden of measuring and reporting on greenhouse gas (GHG) emissions imposed by the carbon tax regulation has further strained the resources of industries. Even more, the provision in the carbon tax for substantial tax-free allowances for emissions, such as allowances for businesses that use carbon offsets to reduce their tax liabilities and performance allowances for businesses that reduce the emission intensity of their activities (National Treasury, 2014), increase the pressure on businesses to take actions that enable them to comply with the law and reduce their emissions.

The South African National Cleaner Production Centre, a national government program, has been since its inception in 2002, promoting resource-efficient and Cleaner Production (RECP) strategies that assist industries in reducing their resource consumption and intensity of carbon emissions. The uptake and implementation of resource efficiency projects in the manufacturing industry have been great but recently declined due to the economic recession the country has been experiencing. This has also resulted in manufacturing plants regarding investment in implementing resource efficiency projects as being of low priority (NCPCSA, 2018), which has resulted in companies opting to implement no low-cost projects. This research was designed to determine the benefits of RECP implementation in reducing carbon emissions and, therefore, reducing carbon tax for the manufacturing industries under these economic and financial constraints.

1.2. Problem Statement

Manufacturing industries are the backbone of the South African economy and vital to modern society, but their production processes are the main source of GHG emissions (IRP, 2020). A carbon tax was introduced mainly to address the increase in greenhouse gas emissions from South African industries, primarily to achieve a reduction in greenhouse gas emissions by changing producers and consumers and encouraging the consideration of mitigation and adaptation strategies through their investment decision and incentives for low carbon technologies (Rasmeni and Pan, 2014).

Previous studies have investigated the relationship between energy use, and carbon emissions, of the manufacturing industries and, the implications of a carbon tax on manufacturing industries separately. They have found that energy use is positively related to excess carbon emissions and a carbon tax reduces carbon emissions (Johnston, 2012). On the other hand, some literature has managed to validate the potential of resource efficiency in climate change mitigation through its potential in reducing GHG emissions (IRP, 2020). The potential of resource efficiency projects in reducing GHG emissions has not been demonstrated in terms of their contribution to the reduction in carbon tax liabilities. Investment in the implementation of energy efficiency projects is among the barriers in most industries (Parker, 2016), yet companies liable for a carbon tax are financially burdened with carbon cost, for up to 40% of their carbon emissions. Evaluating the contribution of RECP implementation to carbon tax liabilities can increase RECP uptake and implementation by industries to reduce their carbon footprint and carbon costs, hence the study assessed the benefits of RECP implementation in reducing the carbon emission and associated carbon tax costs.

1.2.1. Aim and Objectives

The research aimed to evaluate the potential benefits of the implementation of resource-efficient and cleaner production (RECP) implementation in counteracting the effects of the carbon tax on manufacturing industries. The objectives of the research were the following.

- To determine the reduction in energy consumption and the reduction in carbon emissions resulting from the implementation of resource efficiency projects.
- the reduction in carbon tax due to implemented resource-efficient projects.
- To determine the overall potential financial and operational benefits of these changes.

1.3. Rationale

The carbon tax was designed to reduce the excess GHG emissions from the energy and heavy manufacturing sector. This has been reported to have added more financial burden to qualifying industries due to the requirement to report the baseline emissions and the actual cost of scope1 emissions. As a result, carbon foot-printing has become the primary activity of the industries to determine their energy use patterns and GHG emissions baseline for reporting purposes as per the legislative requirement. This activity has a cost implication for industries when outsourced to external service providers. RECP methodology involves a GHG emissions inventory of all scopes of emissions related to industries' resource use.

The contribution of the RECP methodology implementation in manufacturing plants in reducing the environmental footprint measured in GHG emissions equivalent to the energy use has been widely researched (Ewijk, 2018; Kodisang, 2016; Rasmeni and Pan, 2014) however, there is a lack of research to assess this benefit in terms of carbon tax savings. According to National Treasury, there are additional 5% performance tax-free allowances that companies can tap into over and above the 60% tax-free allowance by reducing their GHG emissions. Performance allowances seek to encourage companies to reduce the carbon intensity of their production processes. This allows companies that can show a reduction in their reported GHG emissions baseline to qualify to reduce their carbon tax liability by an additional 5% of their total emissions liabilities. This research evaluated the contribution of RECP implementation in manufacturing industries to reducing carbon costs through performance allowances and further assistance in measuring and reporting their baseline GHG emissions according to the DEEF national GHG emission reporting regulations.

1.4. Research Limitations

The research focused on three manufacturing plants that managed to implement some RECP projects towards the end of 2019 and early 2020 before the outbreak of the COVID-19 pandemic. This has presented the study with limitations in terms of access to the site for measurement and verification of implementation results, which made the researcher rely entirely on the data provided by the company with some monthly data missing. The pandemic shortened the implementation period and affected the implementation budget, as companies had to re-purpose some budgets into responding to the outbreak of COVID-19. This has also reduced the period for the measurement of results. Other energy source data (coal, gas, and diesel) were not provided as a result of some inconsistency in the data. As a result, only the electrical data were analysed. There is a lack of related studies locally, possibly because the carbon tax became effective in 2019. A few months later, the outbreak of the COVID-19 pandemic, which halted many activities Worldwide, may have contributed to this limitation of the research.

1.5. The layout of the Research Report

The research report has 5 chapters. The first chapter looks at the orientation of the study, which gives an overview of the study by touching on the origin of a carbon tax and a key concept of Resource Efficient and Cleaner Production (RECP). The chapter also explains the aim and objectives of the study. The second chapter covers the literature review and the conceptual framework that identifies the link between RECP, climate change mitigation, greenhouse gas emissions, and carbon tax. The third chapter contains the research methodology that the researcher used to conduct the research. The fourth chapter presents the research results obtained from the collected data. The qualitative and quantitative data findings are described separately to ensure that the findings are easily understood. The fifth chapter contains the results, discussions, recommendations, and conclusions.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Human activities have resulted in adverse impacts on the environment since the beginning of the industrial era, one of the most significant impacts being an accelerated increase in the levels of greenhouse gas emissions (GHGs) in the atmosphere (Garidzirai, 2020), which has resulted in increased global warming over the last century. The result is a long-term change in our climate, including increases in Earth's temperatures, changing rainfall patterns, rising sea levels, and decreased crop production due to drought. This resulting impact on climate change is much greater than that of natural processes, due to its contribution to Greenhouse Gas Emissions (GHG) and reflectivity or absorption of the sun's energy (IPC, 2013). Recently, South Africa experienced the impacts of climate change through threats of 'Day Zero' in water availability resulting from a severe drought that affected the Western Cape region (PWC, 2020).

The use of fossil fuels as a source of energy is the primary human activity that releases the most anthropogenic carbon dioxide (CO2) (GHG emissions) into the environment. Driven mainly by the country's energy demand and supply crisis, the abundance of coal mineral resources, and the reliance on heavy manufacturing for economic development, fossil fuels as a source of energy is a catalyst for economic development in South Africa. As such, the reliance on the abundant coal resources for energy generation, while generating environmental pollution through carbon dioxide (CO_2) emission (Garidzirai, 2020), has been regarded as the greatest contributor to the overall increase in greenhouse gas emissions (GHG).

Industries are the cornerstone of the South African economy, and worldwide industrial processes are rated the second largest emitter of GHG emissions, contributing a large part of total GHG emissions (Stols, 2010). Statistics show that energy use contributes more than 90% to greenhouse emissions in South Africa from the resulting increase in carbon dioxide emissions (Nuryartono and Rifai, 2017). Reducing industry GHG emissions will significantly mitigate climate change. As such, climate change mitigation measures that target the industry's GHG emissions are the most important in effectively reducing the impact thereof. Applying these climate change mitigation measures to industrial processes will yield great results. The carbon dioxide emissions resulting from fossil fuels (coal) are the highest among the GHG emissions (Nuryartono and Rifai, 2017).

2.2. Climate Change Mitigation

According to the IPCC (2007), climate change is defined as the directional change in the state of the climate that persists over extended periods due to natural variability or human activity. It has both direct and indirect effects on the natural environment. Countries have started a discussion about cutting down on greenhouse gas (GHG) emissions as the effects of climate change on the environment continue to worsen. The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 to strengthen the global response to climate change after an Intergovernmental Panel on Climate Change (IPCC) was established in 1988. Following this, the international agreement known as the Kyoto Protocol was ratified in 1995. The Kyoto Protocol is a commitment to reduce greenhouse gas (GHG) emissions by at least 5% below the level in 1990 by 2012 (Steenkamp, 2018). It is focused on Annex 1 countries. A legally binding climate change treaty known as the Paris Agreement was ratified in 2015 by 196 nations at the United Nations Conference of Parties as a result of these commitments from the Conventions and Protocols. South Africa, the developing country that is not required to set targets and is not an Annex 1 country, ratified the Paris Agreement only in 2016 by becoming a low-carbon and climate-resilient nation, establishing targets for reducing greenhouse gas emissions, and taking measures to combat climate change (DEA, 2017).

As part of its commitment to these agreements, South Africa has put various legal and policy measures in place, including the National Climate Change Response Strategy for South Africa to address Climate Change (NCCRS), the National Climate Change Response White Paper (the ‘White Paper’), and the National Development Plan (NDP), which outline and establish all mitigation strategies and action plans (DEA, 2017). Climate change mitigation measures include carbon offset methods such as Clean Development Mechanisms (CDM), carbon trading, carbon sequestration, carbon tax, and shifting to cleaner energy (National Treasury, 2019). CDM allows GHG emitters to compensate or offset their GHG emissions by investing in projects that reduce emissions elsewhere (Steenkamp, 2018). This mechanism includes renewable energy and energy efficiency projects that generate carbon emissions reduction credits sold to countries to meet their obligations to reduce emissions. Cap-and-Trade, a carbon trading method, promotes the reduction of greenhouse gas emissions by setting limits on emissions allowances and allowing transfer between different countries under the Kyoto Protocol (Pillay, 2014). Carbon sequestration is also one of the carbon offset mechanisms. Activities such as planting trees and preserving carbon stocks in the forestry sector play a role in reducing GHG emissions (Kalaba, 2020).

2.3. GHG Emissions in South Africa

South Africa is one of the world's leading polluters with a global contribution to greenhouse gas emissions of more than 500 metric tons of equivalent carbon dioxide emissions, which amounts to approximately 1.2% of global greenhouse gas emissions. The country ranks as the world's 14th largest emitter despite being considered a non-Annex 1 country. It is also the largest GHG emitter in Africa due to its dependence on fossil fuels as its main source of energy to sustain the heavy manufacturing industries (World Bank, 2019). The energy sector is responsible for about 79.5% of total GHG emissions in the South African economy, with land-use change contributing about 9%, industry contributing about 7.7%, and the remaining 3.6% from the waste sector (DEA, 2019). The total national GHG emissions expressed in terms of the contribution of the economic sector vary, with the largest GHG contributed by electricity generation at 42% and industry at 27% (DEA,2019), as indicated in Figure 1 below.

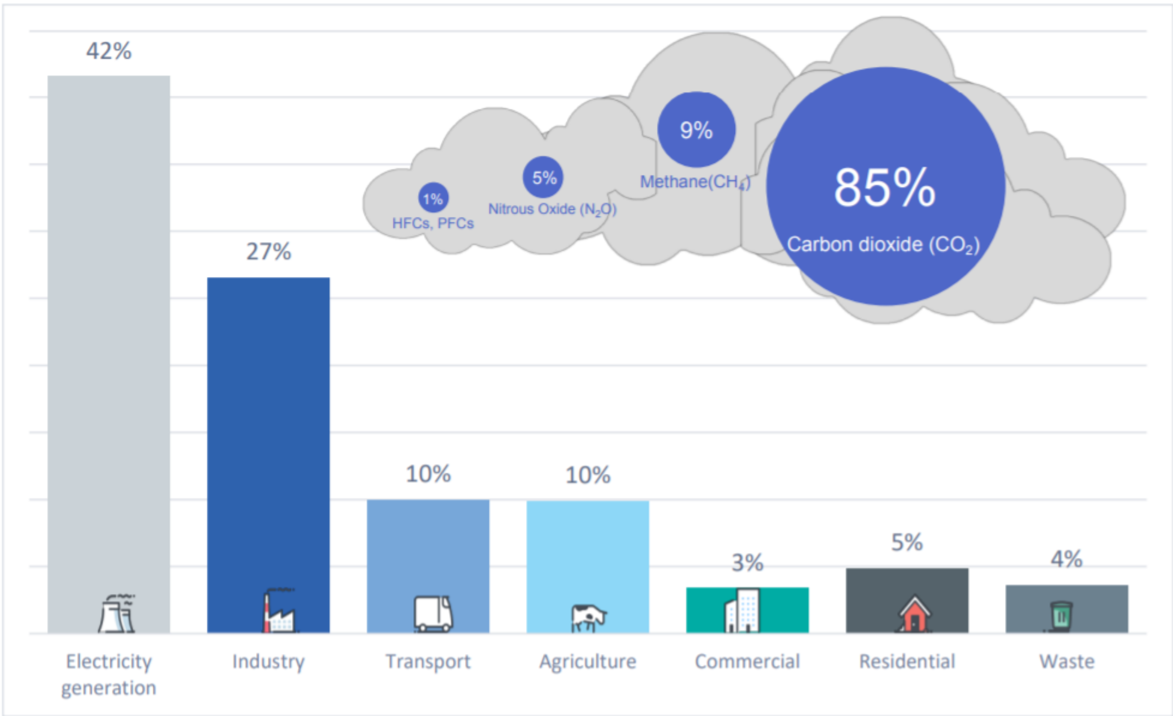

Figure 1: Total gross national GHG emissions by economic sector (Source: DEA, 2019)

Most of the emissions that result from the energy and industry sectors are carbon dioxide (CO_2) due to the use of coal for electricity production. Through the Independent Power Producer Procurement Program, the government has implemented measures to promote energy efficiency and established renewable energy (RE) industries to significantly reduce CO2 emissions, guarantee electricity supply, and diversify the nation's energy sources (Dippenaar, 2018). GHG emissions will be significantly reduced and a contribution to the global goal of reducing climate change will be made by focusing on the energy and industry sectors to reduce carbon emissions (Kalaba, 2020).

2.4. GHG emission reporting, Scope of Carbon Emissions, and Emission Factors

Governments have established mandatory GHG measurement and reporting schemes under which energy-intensive industries report their GHG emissions and, in some cases, additional climate-change-related information. According to the National Environment Management, the Department of Environmental Affairs, which is currently referred to as the Department of Forestry, Fisheries, and Environment (DFFE), is responsible for putting GHG reporting requirements into action: The National GHG Emission Reporting Regulations (NGER) are used to enforce the Air Quality Act of 2004 (Act No. 39 of 2004), also known as NEMQA. t was first proposed as measurement, reporting, and verification (MRV) in 1997 as part of the UNFCCC to track greenhouse gas (GHG) emissions. Later, it was submitted as part of the NEMQA and included as a carbon tax regulatory framework (Boyd *et al*., 2013). This has seen energy-intensive industries embarking on carbon foot printing exercises to align with the regulation, to measure and report all their emissions scopes (G-Protocol, 2011), as categorised into scope metrics of carbon emissions measurement by the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD).

The three scopes of emissions include scope 1 emissions, emissions measured from the organisation's direct activities such as process and fugitive emissions, and emissions from mobile equipment owned or controlled by the organisation (Eskom, 2019). Scope 2 emissions are from indirect activities such as carbon emission equivalents from purchased electricity or heat. Scope 3 emissions are related to the organisation's supply chain, including business travel and outsourced transport (Olatunji *et al*., 2019). These GHG emissions from outsourced activities not controlled by the organisation are harder to manage and therefore only partially considered in a GHG Inventory (Eskom, 2019).

The internationally accepted emissions factors, reporting methodologies, and tools developed under the Guidelines for National GHG Inventory by the IPCC are the most appropriate guide to determining GHG emissions. The various GHGs' global warming potential (GWP) is represented by these emissions factors. They are based on a three-tiered strategy, with high-level default emission factors (EFs) and/or net calorific values (NCVs) as the first tier. The accuracy and degree of uncertainty of GHG estimates decrease as one progresses to tiers 2 and 3 (IPCC, 2006). Using the National Greenhouse Gas Emission Reporting Regulations (DEA, 2017), all GHG emissions—including methane—can also be converted using country-specific EF and/or NCV values from the activities of the organization to a carbon equivalent expressed as tonnes of equivalent CO2 (tCO2e) (IPPC, 2006). Industries use electricity generation sources with emissions factors of 1.06 kgCO2e (Eskom, 2019)

2.5. Carbon tax in South Africa

In terms of the Paris Agreement, South Africa's commitments to reduce emissions by 34% below baseline by 2020 and by 42% by 2025, have led to the implementation of a carbon tax effective from June 2019 as an instrument to achieve these targets. It forms part of the National Climate Change Response Policy (NCCRP of 2011). And the National Development Plan (DEA, 2015). Carbon tax follows other environmental taxes like electricity and fuel levies and requirements for entities to report their annual GHG emissions and future planned carbon emissions incentives, all of which have failed to achieve the required environmental objectives. Carbon tax policy was developed through extensive stakeholder consultation. Its first discussion paper was published in 2010, followed by its policy paper approved in 2013, which provided the basis for the initial draft of the Carbon tax bill and publication in November 2015. The second draft was approved in August 2017 and submitted to the National Treasury in November 2018. It was signed into law in May 2019 (National Treasury, 2019) see Figure 2, showing Carbon tax timelines.

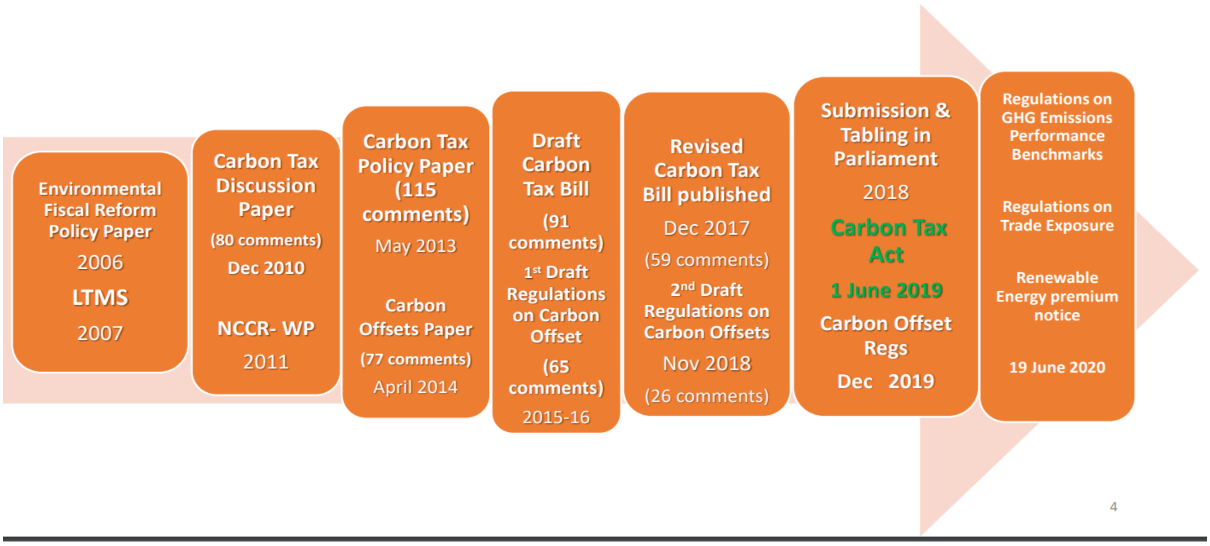

Figure 2: Carbon Tax development timelines (Source: DEA, 2017)

Defined as a tax on fossil fuel inputs that is levied on industry-specific CO2 emissions (Hugh, 2017). Carbon tax is meant to reduce carbon emissions related to the carbon content of fossil fuels (Alton, 2014). This expands on Hasset (2007)'s definition of a carbon tax as a market-based instrument that directly taxes the amount of carbon in fuels to raise prices for emissions.

The goal of a carbon tax is to "internalise externalities related to anthropogenic climate change," which simply means to include costs of the impacts of human activities on climate change, bringing "the price of carbon closer to its true social cost (van Heerden *et al.*, 2016 p714).

Carbon tax aims to disincentivise investment in future carbon-intensive technology or processes and encourage energy efficiency by utilising alternative and cleaner technologies when replacing/renewing machinery, technology, or processes (van Heerden *et al*., 2016). This has seen South African industries (for example, Sasol) initiating several projects to reduce greenhouse gas emissions through operational energy and process efficiency (Sasol, 2019).

Initially proposed at R120/tCO_2-equivalent in its first phase, which began in June 2019 and ended in December 2022, the carbon tax rate increased in 2020 to R127/CO_2e, increasing annually by CPI+2%, this year the carbon tax price is R 134/t CO_2e (PWC, 2020). It is currently levied on scope 1 GHG emissions resulting from fuel combustion, industrial processes with a thermal input capacity of more than 10MW, and fugitive emissions (National Treasury, 2019). Carbon tax highly affects heavy manufacturing industries like mining, cement, chemical, steel, and iron-making companies (Kalaba, 2020), as the main source of emissions from fuel combustion, process, and fugitive emissions due to their heavy manufacturing processes' reliance on energy. Its implementation in the first phase has included allowances to promote the further reduction of carbon emissions; this includes a basic tax-free allowance of up to 60% carbon emissions from fossil fuel combustion, a performance allowance of 5% for industrial process emissions, and fugitive emissions reduction as well as trade exposure, carbon budget and carbon offset allowances (National Treasury, 2019). The National GHG emissions reporting regulations require companies to report annual GHG emissions generated from fuel combustion and industrial process activities and planned future carbon emissions to determine carbon tax basic and performance tax-free allowance. For the performance allowance, industries should show their annual reduction in GHG emissions, whereas for the carbon budget and offset allowances. Industries need to invest in offset projects elsewhere (National Treasury, 2019).

The carbon tax has been designed to reduce GHG emissions and is imposed primarily on industries (that generate emissions within scope 1) as the main contributor to the total GHG emissions. This increases production costs for energy-intensive industries due to increased energy prices and the introduction of the carbon tax. Studies show that industries need to improve their energy efficiency, as it is considered the most promising measure to mitigate climate change (IEA, 2017). As a result, increased costs for greenhouse gas emissions and energy consumption have a negative impact on a company's ability to compete in the market, making increased resource and energy efficiency in the industry essential from both an environmental and an economic point of view (Johansson & Thollandor, 2018).

2.6. Other measures to reduce GHG emissions

Many measures have been developed to reduce GHG emissions, in response to the country's established goals for reducing GHG emissions of 34% and 42% by 2020 and 2025, respectively. These measures include carbon offsets (such as Clean Development Mechanism (CDM), Exchange Trade Funds (EFTs), and RECP. A carbon offset is defined as one of the CDMs used by companies to reduce their carbon tax liability by reducing carbon emissions elsewhere or investing in carbon sequestration projects (National Treasury, 2019) that can be traded through carbon markets to compensate for greenhouse gas emissions from onsite activities (ODI, 2010). Carbon offset is cheaper to achieve than investment in a firm's operations (Ramseur, 2007) to reduce carbon emissions. Investment in carbon offset projects is expected to generate considerable sustainable development benefits for South Africa, including creating jobs, reducing land degradation, encouraging energy efficiency, and low carbon growth (The Carbon Tax Act 15,2019).

Some examples of carbon offset projects currently running in South Africa include the Nova and Sakhile Project, which reduces ambient air pollution and greenhouse gas emissions by implementing an alternative ignition technique that causes households to switch from a less efficient ignition technique with significant greenhouse gas emissions to a technique that results in considerably fewer emissions that is more efficient than the conventional bottom-up technique. The technique is now adopted by households that use coal for domestic cooking, water heating, and ironing (Sasol, 2019). Another example is carbon neutral flights offered by South African Airways, which involve funding carbon offset schemes to offset carbon emitted into the atmosphere, mostly during take-off and landing (Dube and Nhamo, 2019). This was achieved by purchasing Ugandan wood stoves, which become their carbon credits and planting Spekboom trees in the Eastern Cape, which industries buy to compensate for their emissions (Bolus, 2016). These examples of carbon offset allow the carbon balances to move towards neutral but do not reduce the organisation's actual GHG emissions. However, RECP is one of the measures that can reduce the actual GHG emissions of the organisation.

2.7. Resource Efficiency and Cleaner Production

Natural resource (energy, water, raw material) consumption in industries brings productivity and prosperity to the country, but industries' production is linked with the generation of environmental emissions and pollutants (Hossain, 2015). Resource-Effective and Cleaner Production (RECP) responds to this pollution as a preventive environmental measure. It reduces the intensity of carbon per unit of production while generating financial profit for the industry (Hossain, 2015). The concept of Resource Efficient and Cleaner Production (RECP) has been widely defined since its inception in 1990. It was first defined as the continuous application of preventive environmental management strategies to processes, products, and services to increase efficiency and reduce risks to humans and the environment (UNIDO, 1999). The definition was later refined as a methodology that identifies inefficiencies throughout the life cycle of production by finding opportunities to improve how natural resources are extracted, processed, used (reused, recycled, and recovered), and disposed of to achieve greater economic and social gain while minimising negative environmental impacts (Vargas *et al*., 2014).

RECP in the manufacturing process looks at resource inputs, which include energy, water, and material, and resource outputs, which are product and waste, to reduce input materials by improving the efficiency of their use, resulting in reduced waste and associated emissions such as carbon dioxide. This is evident from a life cycle and value chain perspective, as resource efficiency becomes a requirement to reduce the total environmental impact of the production and consumption of goods and services, from the extraction of raw materials to the final use and disposal (Page, 2018). RECP strategies have been shown to increase the productive use of natural resources, minimize waste and emissions, and promote safe and responsible production (UNEP, 2011).

The measure of resource efficiency has been described as changes in the number of resource inputs used to generate economic output (UNEP, 2012). RECP brings out the element of accountability in resource use, which is described in terms of the number of resources used and carbon emissions produced per unit of production and the interventions to improve the efficiency of that production by reducing the resource used per the same unit of production and the reduced carbon emission. Resource efficiency improves the environmental and economic parts of production, commonly referred to as 'doing more with less' (Flachenecker and Rentschler, 2019).

2.7.1. RECP Methodology

The National Cleaner Production Centre South Africa (NCPC), since its inception in 2002, has been mandated to assist industries in implementing RECP methodologies to reduce environmental footprint and improve competitiveness. The RECP process, as facilitated by NCPCSA at the plant level, is a stepwise methodology that enables the identification of process inefficiencies from resource use and CO_2 emissions associated with the entire process and recommends interventions for improvement of process and technology efficiency. The process follows the principle of Plan, Act, Do and Check and can be summarised in five main steps: estimation of resource use, waste, and carbon emission generation; source and cause analysis; identification of possible interventions to reduce resource use, waste, and carbon emission; implementation of selected interventions; and follow-up and continued work (Lindhqvist, 2013) as indicated in Figure 3 below.

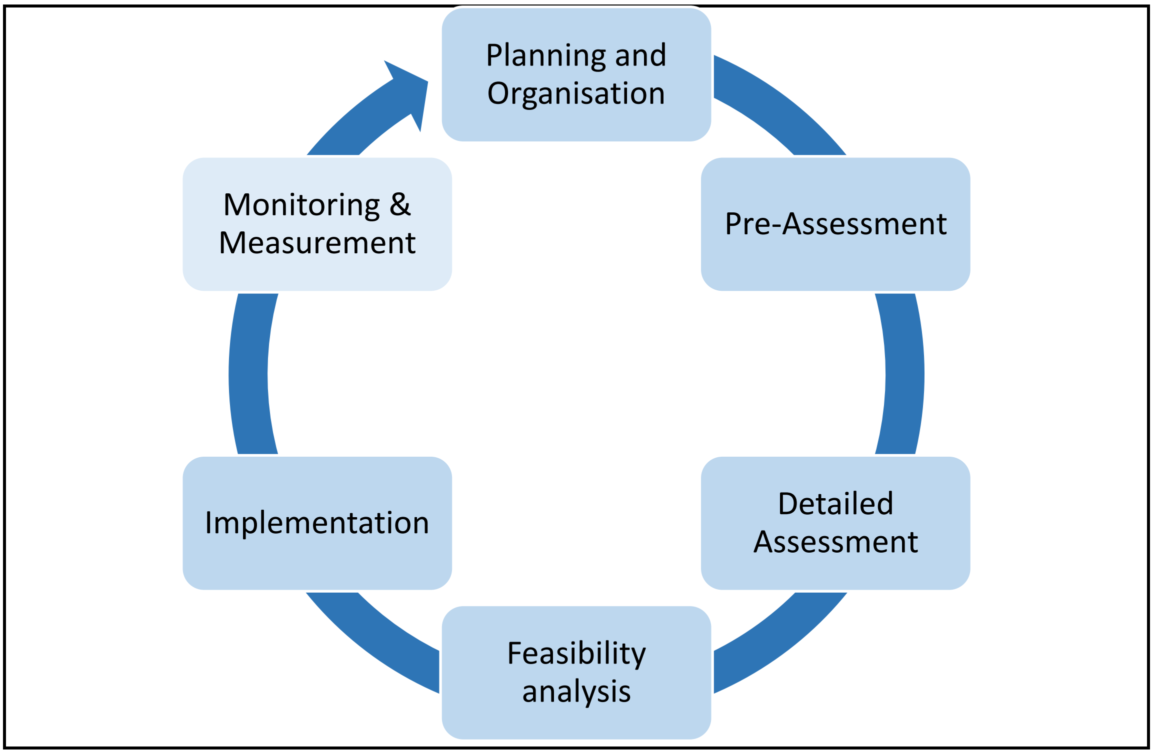

Figure 3: RECP Process diagram showing systematic steps of RECP implementation in a company (Source: NCPCSA, 2010)

The process starts with an initial meeting with the company to establish the scope and limit of the process. The meeting assists in identifying the resources required like time, budget, and a team of personnel to be part of the RECP processes to lead and champion the project within the entire company to drive the implementation. The process involves compiling detailed balances of electricity, water, and waste balances and a GHG emissions inventory, developing a resource baseline, identifying resource performance indicators, and interventions to optimize resource usage and emissions reductions. Using regression analysis, the resource baseline is established to determine future resource performance improvement. Feasibility analysis is also carried out to identify the technical, economic, and environmental benefits, motivating companies to allocate a budget for implementation (NCPC,2018).

The RECP methodology also includes a carbon inventory of the energy used, which is the first step in carbon auditing. Carbon auditing or foot printing is a strategic approach that allows the identification of the area with the most significant emissions and opportunities for reduction through the application of good practices (Fernando and Hor, 2017). Post-implementation monitoring and measurement to determine performance improvement in resource use set new targets and review indicators are performed to evaluate the overall impact of the RECP implementation.

2.7.2. Resource Efficiency Improvement Indicators

Resource efficiency is important to improve economic and environmental performance, and collecting relevant data is vital to identify its improvement (Kubule *et al.,* 2016). The determination of industrial facility resource/energy savings is conducted primarily to comply with legal requirements, meet sustainability goals, quantify greenhouse gas emissions, cost savings, and as a way to demonstrate energy performance (Therkelsen *et al*., 2016). There are several resource improvement indicators used to measure resource efficiency performance improvement. This includes an absolute basis, specific energy intensity (SEC), and normalisation basis (resource baseline). The most reliable way to determine energy savings is by calculating the difference between the energy accounted for during an established baseline and the reporting period. This method is called normalisation (resource baseline determination) - a reference tool that allows the organisation to compare resource performance before and after a change is made to a site or system (IEE, 2016). It involves identifying relevant variables that affect energy consumption (in most cases, it includes production, weather-related heating, and cooling degree days depending on the nature of the production process) and developing models of energy consumption over a period as a function of the variable to derive a modelled energy consumption (Therkelsen *et al*., 2016).

Energy saving through this method can be determined using actual energy consumption compared to modelled/forecasted energy consumption, also referred to as expected energy consumption. This method is considered the most suitable method to determine true energy performance improvements due to its ability to remove the effects of variables related to equipment and processes (such as factors related to weather and production volumes factors) on energy consumption (Therkelsen *et al*., 2016). The main challenge of this indicator is accounting for the different variables affecting energy consumption. This is sometimes due to a lack of reliable and accurate data in many cases. This method uses regression analysis, a technique that identifies relationships between one or more dependent and independent variables using mathematical models on a set of data (Therkelsen *et al*., 2016). In this case, it is energy consumption. The independent variable is production, for energy analysis for a manufacturing plant not affected by weather or other energy drivers not related to production.

Resource intensity measures the resources (energy, water, and material) needed to produce, process, and dispose of goods or services (Gajdzik and Sroka, 2021). It is used in decision-making, budget forecasting for production, and environmental sustainability, which is also an important measure of competitiveness (Gajdzik and Sroka, 2021). This makes resource intensity a key component for resource management and future planning of resources used in production processes and, therefore, measures the company's resource performance. It is mostly expressed as the ratio of resource consumption per production unit (products), also called specific energy consumption (SEC), measuring the whole facility's or process' resource consumption, including baseload, which presents a good resource performance indictor for processes without baseload consumption and not affected by other factors other than production.

2.7.3. Barriers and Benefits of RECP implementation

Barriers to RECP implementation have been widely researched. It has been suggested that a lesser improvement in resource efficiency is mainly due to financial constraints that prevent investments in RECP projects needed to improve resource performance. This demonstrates that investments may fail to materialise even when cost-benefit analysis and evaluations of investments in resource efficiency conclude positive net benefits (Flachenecker and Rentschler, 2019). The lack of awareness of the benefits of resource efficiency within all levels of personnel and the lack of internal capacity were also highlighted as barriers to the implementation of RECP in industrial plants (Page, 2017). Other barriers to the implementation of RECP may be that firms do not prioritise RECP projects due to other internal projects that are more crucial to their bottom lines (Flachenecker and Rentschler, 2019).

Resource efficiency has been regarded as a policy objective that has the potential to yield both economic and environmental benefits. However, the economic factor can hinder resource efficiency progress in achieving its intended outcome (Flachenecker and Rentschler, 2019).

The benefits of RECP implementation override barriers, as resource efficiency has been shown to improve competitiveness and reduce greenhouse gas emissions (Rosenstock and Flachenecker, 2018). In addition to the benefit of the policy, RECP has been shown to improve process and equipment efficiency, the health and safety of employees, and overall business performance (Flachenecker and Rentschler, 2019). A case study by Kodisang (2016) has shown these benefits in the automotive manufacturing industry, whereby the implementation of resource efficiency principles such as process equipment redesign and operational control resulted in reduced energy consumption and related GHG emissions, improved process, and equipment efficiency resulting from process redesign and operational control through the installation of a Variable Speed Drive (VSD). This has also improved the overall baseline model with reduced baseload for future performance improvement determination. Another case study by Govender (2008) of a mining company has also shown the benefits of RECP by reducing energy consumption and related GHG emissions and cost by switching off equipment when not in use. This has yielded 3.7% savings on the annual energy consumption of the mine. Switching off equipment when not in use has also resulted in better health and safety of employees, reducing noise levels and possibilities of accidents during breaks.

2.8. RECP and Sustainable Development

Global GHG emissions have been identified as primarily attributed to the manufacturing sector. Most manufactured goods typically only last one lifetime under current patterns of resource consumption, after which they are discarded. The linear economy, also known as the "take-make-use-discard" model, is extremely inefficient (Martins *et al*., 2014). It not only depletes the planet’s limited resources and create a multitude of waste, pollution, and health issues; it also makes a substantial contribution to GHG emissions (UNIDO, 2019). While many manufacturing organizations are still looking for ways to reduce carbon emissions from their operations, which may indicate a need for scaling up RECP in the industries, some manufacturing organizations have accepted the reality of carbon emissions and implemented resource efficiency measures. Industries are under a lot of pressure to include carbon footprint exercises in their operations now that the carbon tax has been implemented (Olutanji et al., 2019).

Research has shown that RECP reduces waste generation and environmental footprints (GHG emissions) at the firm level, initiates circular economy practices (Page, 2017), and directly contributes to achieving climate change-related targets (UNIDO, 2019), which contributes to the fundamentals of industry’ sustainability, proving the critical importance of improving resource efficiency in manufacturing. A case study in three mining companies has proven that improved energy efficiency through fixing leaks on compressed air systems during maintenance, heat recovery of waste heat from compressors, and reuse to heat process water were some of the most effective ways to reduce energy consumption and GHG emissions (Johnson, 2012).

Resource efficiency is an important component of national sustainability goals, as highlighted in numerous policy initiatives (Flachenecker and Rentschler, 2019). One essential component of achieving the Sustainable Development Goals (SDGs) is enhancing resource efficiency to improve people's well-being while minimizing resource consumption and environmental impacts. RECP has been linked directly or indirectly with SDG 6 for Sanitation and Clean Water, SDG 8 for Economic Growth and Good Work; SDGs 9 for Innovation and Infrastructure in the Industry, 12 for Responsible Production and Consumption, and SGD13 for Activism Against Climate Change. As it addresses the three thematic areas (water, energy, and waste/emissions) and results in improved operational efficiency and performance, mitigation of GHG emissions, and climate change, RECP implementation can assist in achieving these goals (UNIDO, 2019). By advocating for water efficiency, reuse, and recycling, it responds to the challenge of increasing water scarcity in a further way. In addition, It also encourages the efficiency of raw materials by reducing the use of virgin materials through innovative ideas of reuse and recycling of waste or by-products, which subsequently provides decent jobs and slows down environmental degradation (NCPCSA, 2019).

UNEP emphasizes that to achieve such sustainability, today's linear material flows through the economy must become circular through the development of efficient and inclusive infrastructure systems, standardisation, reuse, recycling/remanufacturing, and intelligent product design. (UNEP, 2017). An example in the case of RECP implementation of the best management strategy in pallet manufacturing processes, of selling sawdust and waste offcuts to other companies for reuse has shown to change what used to be a linear material flow process to a circular one, resulting in waste material flow to other industries for reuse. This has not only reduced the cost of disposal, raw material, and energy of produced waste, but it has reduced carbon emissions associated with landfill waste emissions (Vargas *et al*., 2019).

2.9. Conclusion

The literature review has highlighted the existing knowledge about the significant contribution of manufacturing industries' processes to the country's GHG emissions levels. It has also summarised the Resource Efficient and Cleaner Production (RECP) methodologies, their application in industries, and outcomes in improving resource efficiency, measured by reduction in resource use (Energy, Wate, and material), equivalent GHG emission, and cost-saving. As such the knowledge of RECP implementation in industries and its benefit in reducing GHG emissions was found to strongly exist. The literature has also found a lack of finance among factors prohibiting industries to implement resource-efficient interventions/projects, which also results in the actual benefits of RECP implementation not realised. The contribution of RECP to respond to various policy actions like sustainable Development Goals, industries' competitiveness and overall resource performance have been widely emphasised but its evidence lies in the actual RECP projects implemented by industries. Hence there is a gap in knowledge of the contribution of RECP implementation in reducing carbon tax liabilities and a need to link the GHG emission reduction benefit of RECP project implementation with the carbon tax liabilities of the industries

CHAPTER 3: RESEARCH METHODOLOGY

This chapter addresses the research methodology used, data collection and analysis used for the research, and the study sites at which the research was conducted. The tools for data collection, guided by the research objectives, are also discussed. The chapter also covered ethical considerations and highlighted the limitations of the study.

3.1. Research Design

The research design clearly outlines the data collection procedure and the methods used to collect and analyse data to answer the research question (Lelissa, 2018). This research followed a mixed-methods triangulation research design (Greene, Caracelli, and Graham, 1989), procedures for data collection, analysis, and interpretation, which allows the investigator to collect data and analyse different but complementary data sets, integrate the findings, and draw conclusions, using both qualitative and quantitative approaches (Creswell and Garret, 2008). The quantitative approach used energy consumption data before and after RECP implementation, a research strategy that involves empirical investigation using multiple sources of evidence (Robson, 2002), and provides a baseline from which the intended results can be deduced. The qualitative aspect of the study involved semi-structured interviews and conversations about the topic with company managers and expert consultants. This approach was used to find possible relationships between the implementation of RECP, the reduction of greenhouse gas emissions, and carbon tax reduction from the point of view of the company managers and expert consultants' points of view. Several research instruments were used to achieve the research objectives, including a review of the literature, RECP assessments, and interviews.

3.1.1. Study Area

Five manufacturing plants that participated on the NCPCSA's RECP Implementation Expert training, were initially selected for this study. The companies were selected based on their willingness to participate in the research study, commitment to implementing the RECP interventions, and their level of GHG emissions associated with their production processes. Additionally, the availability of company managers to contribute and provide pertinent data for the investigation was a crucial criterion. However, due to the COVID-19 outbreak and management's lack of commitment to implement the proposed RECP interventions only three of the five manufacturing plants were finally used as the study area for this research. The other company affected by COVID-19 preferred to focus on production and repurposing their budget for implementation of other business competing matters, while the other company closed for long periods during the COVID-19 lockdown, limiting the time for measurement and verification of some implemented projects.

In contrast, another company could not afford to allocate time and resources to projects for this study. Among the three participating companies, were steel, glass, and cement manufacturing plants. The participating companies are located within the City of Johannesburg and Ekurhuleni Municipalities in the Gauteng Province. The distance between locations is approximately 15 km to 25 km. The participating manufacturing plants use energy from Eskom, with special exemption from load-shedding, and their supply of water from Rand Water, with a supplement from borehole water. Their raw material varies, for steel mill, scrap metals are the main input material, for glass manufacturing, raw material includes, sand, limestone, and recycled culets, and for Cement manufacturing, the main raw material for the production process includes limestone and clay. The production is measured in tonnes of products (steel, glass, and cement) produced.

3.2. RECP projects implemented

RECP projects identified during assessments included system optimisation, efficient equipment or technology, process redesign, and operational control projects. The projects were evaluated based on their environmental and financial benefits, ranging from no-cost projects to low-cost, and high-capital investment projects. Companies did not implement all recommended projects, but most no-cost and low-cost options were implemented first; this was due to the financial constraints and the state of the economy worsened by the COVID pandemic. The choice of RECP project implementation was mostly dependent on the investment cost. Data related to the type of project implemented and the cost of implementation were compiled for further analysis regarding the impact on energy use and equivalent GHG emissions.

3.3. Energy Use before implementation

Quantitative data were collected using RECP assessments, with the help of company managers as RECP champions who have access to company information and documents and expert consultants who have extensive knowledge of RECP, energy efficiency, and manufacturing process equipment. The evaluation activities for data collection comprised the following:

- Compiling Historical Energy Consumption and GHG emissions inventory for 2018 and 2019 before RECP Assessment.
- Evaluating energy management practices, compiling detailed electrical balances on the identified priority energy systems (refrigeration, steam, compressed air, motors, and fans.
- Identifying interventions for energy use optimisation and emissions reductions and performing a cost-benefit analysis on the identified RECP interventions.

The assessment process allowed for energy consumption data before implementation to be collected from electricity bills and production figures. In some energy systems, the consumption data were verified through spot measurements conducted by expert consultants. Monthly data were compiled and quantified a year or two before the RECP assessment in terms of energy consumption per kilowatt-hour and production figures per tonne for the year 2018/ 2019. These data were used as baseline data to ensure efficiency could be measured after implementation. A GHG emissions inventory was also conducted using only energy consumption data to quantify the equivalent GHG emissions and carbon tax using the electricity emissions factor of 1.06 (Eskom, 2019) and the 2019 carbon tax rate of 120/CO_2e.

The manufacturing processes were observed to understand where and how energy was used in the plant, highlighting the use of energy when there is no production, associated with the equipment left running during lunch breaks and at the end of the shifts. This also determined relevant variables that drive energy consumption and led to identifying significant energy users and operational control inefficiencies. The load profiles were recorded and used to estimate the electricity consumption relative to production. This was used to identify process inefficiencies associated with RECP interventions and provide direction on the type of RECP projects that can be implemented.

3.4. Energy use after RECP implementation

Energy baseline models were developed using the regression analysis tool to determine the energy savings after RECP implementation. The baseline methodology used involved performing a multi-variate regression analysis. The dependence of energy consumption on one or more independent relevant variables can be estimated using this statistical technique (Therkelsen *et al*., 2016), which are quantifiable factors that affect the facility's energy consumption. For the three plants, three relevant variables - production volumes, heating and cooling degree days (HDD and CDD)- the measures of how cold or warm a location is compared to the average outdoor temperatures recorded for a location to a standard temperature - were selected, as the more extreme the outside temperature, the higher the number of degree days and the higher levels of energy use for space heating or cooling (Boussa, 2016). The station chosen for the HDD and CDD values was Johannesburg International Airport with a base temperature of 18 C. Regression analysis was performed between plant energy consumption and production volumes, HDD and CDD. Based on the coefficients of the analysis result (adjusted R2 and p values, the relevant variables are confirmed to be the main energy drivers of the facility, provided that R^2 is greater than 0.75, with p values less than 0.05. In this study, CDD and HDD were eliminated as relevant variables based on analysis results and remain with production volumes as the main relevant variable impacting plant energy consumption of plants (Therkelsen *et al*.,2016).

The summary results were used to create the energy model, which is an equation that shows the regression scatterplot's best-fit line as $y = mx + c$; where y is the amount of energy used each month, m is the amount of energy used per unit of production, and c is the y-intercept, which is the baseload of energy used when there is no production. The energy baseline model, represented by the formulated equation, was used to forecast the expected energy consumption. The expected energy consumption would be the expected energy consumption for the year following the baseline year if the business continued as usual, without RECP implementation or changes in production operations and equipment (NCPCSA, 2019).

Energy consumption data after RECP projects implementation was also collected during the measurement and verification phase (also referred to as the case study phase) from energy bills and electric meters and the production figures. These data were also verified through spot measurements conducted by experts. The energy consumption data were analysed to measure the impact of the RECP intervention implemented. These were performed by comparing the actual energy consumption of the reporting year (2021) with the expected energy consumption without implementation of RECP to determine the change in kilowatt-hours (kWh). The resulting change in energy consumption (reduction or increase in energy consumption) is referred to as energy-saving or de-saving. Change in energy consumption was used to estimate equivalent GHG emissions using Eskom's 2019 electricity emission factor of 1kWh, equivalent to 1.06 kg/CO_2e and the resulting carbon tax savings using the 2020 carbon tax rate of R127/tCO_2e (National Treasury, 2019).

3.5. Interviews

Qualitative data were collected using semi-structured interviews conducted using online platforms such as Zoom and Microsoft Teams, as in-person interviews were restricted due to the COVID pandemic. The respondents included the plant managers or sustainability managers of the three manufacturing plants and RECP expert consultants contracted by the NCPCSA to provide technical expertise during the implementation of RECP. The interviews aimed to gather the respondents' perceptions on the benefits of RECP implementation to establish the relationship between the results of RECP implementation and carbon emissions as well as their equivalent carbon cost or tax. The interview questions were designed to obtain information on the following aspects: carbon emissions measurement and reporting, carbon emissions reduction initiatives, the direct benefits of implemented RECP projects in their resource consumption, and emissions patterns based on the outcome, experience, and knowledge obtained from RECP implementation. Specifically, the questions focused on extracting information on the overall benefits of RECP projects implementation relative to GHG emission and carbon tax reduction, and on understanding the perception of the respondents on the contribution of the RECP projects implementation results in companies' responses to carbon tax legislative requirements, in terms of measuring and reporting carbon emissions and plans to reduce the emissions. Therefore, the interview schedule was prepared to include a focused set of questions, as contained in Appendix E. Separate interview schedules were compiled for company managers and expert consultants to understand each respondent's perception about the result of RECP implementation that is linked to the research question. The formulation of the interview questions was also guided by the roles and purpose of the stages of RECP implementation, and they include:

- The role of company managers and expert consultants in the implementation of RECP, with the intent to confirm if their role in RECP ensures that data are obtained to report on resource consumption patterns and GHG emissions, is obtained.
- The reasons the company participates in RECP implementation, to confirm whether the reasons why the company participates in RECP projects implementation include reduction of carbon emissions and costs.
- RECP methodology used for assessment, monitoring, and measurements: to confirm its contribution to collecting data for reporting consumption patterns and emissions as part of the carbon tax legislative requirements.
- RECP results obtained from project implementation: to confirm if they are reliable in measuring and reducing carbon emissions and associated costs.
- RECP investment cost for project implementation compared to the actual benefits obtained to determine if the cost of implementation is worth the cost-saving realised from RECP projects implemented.

- Compare the cost of implementation with the resulting carbon tax savings from the implemented projects.
- Reduction in GHG emissions from RECP implementation relative to carbon tax reduction.

The format of the response was arranged in the following order: agree and disagree to ensure that their response can be easily evaluated. The responses from the participants were used to assess their understanding and perception of the RECP implementation results in measuring carbon emissions for reporting purposes as per carbon tax legislative requirements, reducing carbon emissions and hence carbon tax liabilities, and establishing the main reasons for manufacturing plants' embarking on RECP implementation.

3.6. Data Analysis

Quantitative data were first obtained by time trend analysis to establish monthly energy consumption patterns for the baseline period. Data were further analysed to establish energy use patterns and relationships between energy consumption and production to determine potential performance improvement indicators. The choice of performance improvement indicators in most cases is guided by international standards (Lawrence *et al*., 2019) as well as the nature of the production processes, for example, the use of Specific Energy Consumption (SEC)/ energy intensity as a performance improvement indicator in a plant with high process inefficiencies presented by baseload may lead to misrepresentation.

Data from RECP projects implemented in the form of several implemented projects, actual energy consumption and resulting change in energy consumption, as well as its equivalent GHG emissions and carbon tax determined during the measurement and verification phase, were further evaluated by comparing the results with the investment costs of the interventions implemented contained in the RECP assessment to determine the simple payback time.

Qualitative data from interviews were analysed using thematic content analysis (TCA), a descriptive presentation of data (Anderson, 2007) to find the agreements and disagreements between the respondents and gather insight into the interview questions. Data from the interview was further evaluated based on levels of agreement or disagreement to determine respondents' perception of the RECP implementation results contribution to GHG emissions and carbon tax reduction and in responding to the reporting requirements as per the legislative requirement.

3.7. Ethical Consideration

This study was set to maintain a high degree of integrity with the following ethical considerations: all participants were requested to participate voluntarily, and the anonymity of the participants was guaranteed. To ensure that participants were allowed to participate in the interview and share company information, a letter or email confirming permission to participate from the company's management was requested. To ensure that participants were allowed to participate in the interview and share company information, a letter or email confirming permission to participate from the company's management was requested. NCPCSA management permission was also granted to allow the use of the NCPC RECP Implementation Program and to ensure that the information was treated as confidential, without mention of company or participant names in the research report. Ethics clearance was provided by the University of the Witwatersrand Human (nonmedical) Research Ethics Committee with the ethics clearance number: HA2005 (see Appendix A) for the copy of the ethical clearance certificate.

3.8. Research limitations and Challenges

The study was originally planned to have five case studies (5 companies), but due to the COVID-19 pandemic, some companies could not complete any RECP implementation. Most of the companies that implemented only focused on the no and low-cost options, with some implementation halted and deferred to when the budget is available. Because of the pandemic, the participants were working from home, interviews had to be done using online meeting platforms, and site visits were not allowed, which led to relying entirely on company managers to provide data. The study was conducted during the COVID-19 pandemic and during periods of load-shedding, which led to disruption of connectivity during meetings and meeting postponement, which ultimately led to some participants losing interest to engage and provide information. Working from home also posed a challenge for participants signing the consent forms and obtaining approval from their company management to participate and share information.

The study focused on the electrical energy data of the RECP assessment and excluded water and waste information. As a result, only GHG emissions equivalent to energy consumption were covered.

CHAPTER 4: RESEARCH RESULTS

This chapter presents the analysis and results of the research data obtained from three manufacturing plants. Different research techniques were applied for data collection and analysis. Quantitative data in the form of energy usage (from energy bills) were compared with energy usage after the RECP project implementation to evaluate the results of RECP implementation. Qualitative data in the form of responses of company RECP champions and consultants from the interview questionnaires were also analysed to understand the perceptions of the company managers and expert consultants on RECP implementation and the benefits thereof.

4.1 RECP Projects

Various resource efficiency projects identified during RECP assessments to address identified areas of inefficiencies in the manufacturing process were implemented. Due to financial constraints and the COVID pandemic, mostly low- to no-cost projects and projects that are part of scheduled maintenance were implemented. At the time of this study, most of the projects that required high capital investment were not yet implemented. The resource efficiency projects implemented ranged from operational control, equipment optimisation, and type of behavioural change projects, depending on each company's identified process inefficiencies of each company (Tables 1a-c).

Table 1:RECP Projects Implemented in Company A

RECP Intervention	Investment (ZAR)
Replacement of (1) inefficient 15A battery charges during maintenance	R 1 097 745
Replacement of the charge room baths and charger with a new acid recirculation system during maintenance	R 2 195 490
Shut down during no production times	R0
Reduce charge profile hours reduction	R0
Charge bath warm-up schedule	R0
	R3 299 635

Table 1 above shows projects implemented in company A. Five projects were implemented out of nine projects recommended, with a capital investment of R3 299 635 and a payback of 11.7 years for two projects that involved replacing inefficient equipment during maintenance.

Previously, the company was replacing batteries and charging room equipment with energy inefficient, which consumes more energy. The investment cost was part of the maintenance budget, annually budgeted as part of the operational cost. The three other projects were operational control projects that did not require financial investment but a behavioural change of the operators. These projects address the baseload energy (energy used when there is no production).

Company B implemented all recommended RECP projects, with most of the no-cost projects implemented immediately, and projects that required more capital investment were later in the year, as shown in Table 2 below.

Table 2: RECP Projects Implemented in Company B

RECP Intervention	Investment (ZAR)
Make use of efficient Trane Chiller External Pump - 7.5 kW	R0.00
Improve Boilers efficiency (controls)	R0.00
Install VSD on the Cooling tower Fans	R28 201.00
Install Compressed air flow meter	R11 125.00
Control Maximum Demand	R0.00
Install efficient Cooling Tower Pump and Fans	R0.00
Upgrade Power Factory from 0.95 - 1	R0.00
Install Light Automation - Time and Daylight sensor	R0.00
Turn off the compressor and air supply during weekends	R0.00
Install VSD on cooling tower pumps - factory 1	R77 387.00
Insulate Chiller Pipes and Tank	R81 320.00
Turn off the Sulzer Cooling Tower - Remove Circulation pumps	R16 778.00
Replace 57W x 32 with 50W LED x 24 lights	R44 167.00
Total	**R258 978.00**

Table 2 above shows thirteen RECP projects implemented by company B with a total capital investment of R258,978 and a payback of 0.3 years. The seven projects were operational control projects, such as operating the equipment at the correct pressure and reducing leaks, and behavioural change projects that require no capital investment, such as turning off the compressors when not in use. Significant improvements were made in these operational control parameters and maintenance procedures. These low/no-cost controls decrease energy usage and involve and encourage employees to be proactive and remain engaged with energy savings on a daily or weekly basis. Six other projects were low to medium-cost projects, which included the installation of efficient technologies like the installation of Variable Speed-Drives (VSD) to increase efficiency and control, light automation sensors, LED lighting chillers insulation, and fixing leaks. This project addressed many areas of inefficiencies in the refrigeration, compressed air, and fan systems of the plant.

Table 3: RECP Projects Implemented in Company C

RECP Intervention	**Investment (ZAR)**
Install Compressed Air Vacuum locking system	R14 000.00
Compressed air saving	R126 372.00
Install solar thermal geysers for change-room	R20 750.00
Install Light sensors for Admin Offices	R35 500.00
Install Meters for monitoring	R97 000.00
Boiler Efficiency improvements	Not available
Install Pipe cladding/insulation to prevent Heat loss	R15 000.00
Total	**R308 622.00**

Table 3 shows the RECP projects implemented by Company C, with an investment cost of R308 622 and a payback of 0.3 years. Company C implemented seven RECP projects. Most of the projects addressed inefficiencies in the compressed air and steam system, piping cladding resulting in heat loss, and energy use when there is no production by lighting in the admin offices left after shifts. This implemented intervention includes compressed air and boiler system, light sensors, and pipe insulation projects.

4.2. Analysis of Energy Use Before RECP Implementation

The three companies' energy consumption data (Company A, B, and C) for the year 2019 before RECP (see Annex B) was found to be 24,733,732kWh, 15,268,240kWh, and 4,081,541kWh for companies A, B, and C, respectively, with their equivalent GHG emissions, carbon tax and performance allowances evaluated as indicated in Table 2. Company B had by far the highest baseline energy consumption, while Company C had the lowest consumption level (see Table 4) below.

Table 4: RECP base year data for Companies A, B and C

Baseline Energy Consumption and Equivalent GHG emissions and Carbon Tax			
	Company A	**Company B**	**Company C**
Baseline Energy Consumption (kWh/y)	24733732	15268240	4081541
GHG Emission equivalent/tCO_2	26218	16184	4326
Equivalent Carbon tax liability ®	1331862	822147	219761
Performance allowance (R)	66593	41107	10988

The regression analysis performed on the energy consumption and production volumes using the energy data presented in Annex C shows a good regression coefficient (R2) and correlations (represented by the value P) for the three companies, as shown in Table 3 below. Company A produced a perfect R^2 of 0.93 and a P value of 0.004 as well as a base load of 653147.5 kWh, also known as the intercept coefficient; Company B produced a good R^2 of 0.81, with a P-value of 0.0123 and a base load of 420691 kWh; and for Company C, R^2 of 0.85, a P value of 0.0324, and a baseline of 85558 kWh was found. Using the regression scatterplots best-fit line formula y = mx + c, the energy baseline models equation for Company A, B and C were established to be y = 1.0363x + 653148, y = 6.2784x + 410691 and y=1.820x+85558, respectively. The energy baseline models were used to forecast the expected energy consumption for the following year.

Table 5: Regression Analysis Coefficient for Energy Baseline Model Development

Regression Analysis Coefficients			
	Company A	Company B	Company C
Intercept Coefficient / Baseload	653148	410691	85558
R Square	0.93	0.81	0.85
P-value	0.0004	0.0123	0.0324

4.3. Analysis of Energy Consumption After RECP Implementation

The actual energy consumption data for the year after RECP implementation (2020) was compared with the expected energy consumption; see Annexes B. This analysis represents the difference in the expected energy consumption- the forecasted energy consumption and the actual energy consumption of the plant for the year 2020. These represent the impact of

RECP projects on energy use. The monthly change in energy consumption was also positive in some other months and negative in some other months (see Figures 4, 5, and 6).

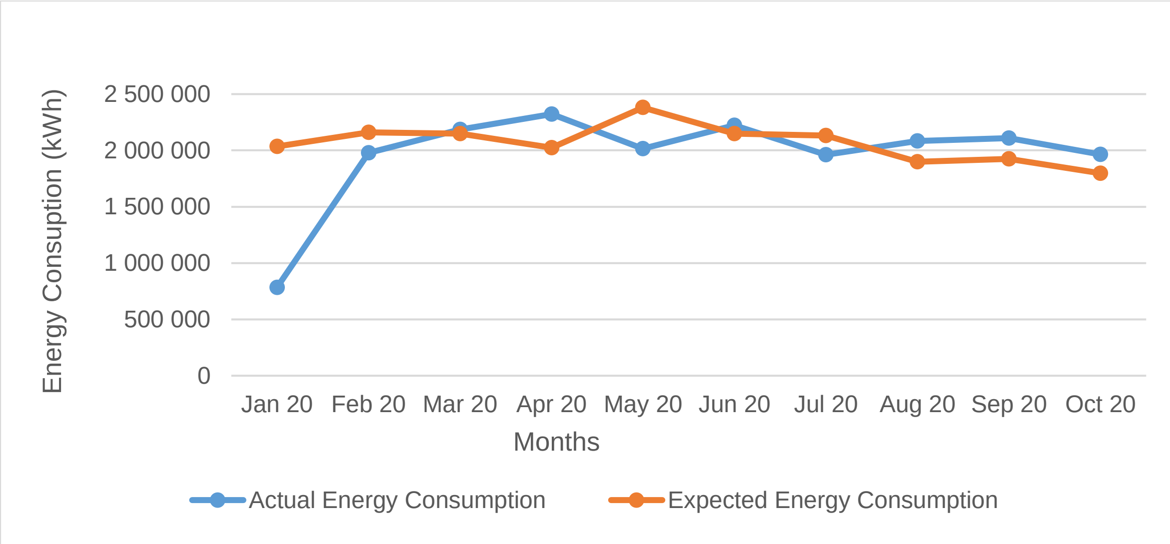

Figure 4: Actual and Expected Energy Consumption for Company A

Figure 4 illustrates the actual energy consumption after RECP implementation compared to the expected energy consumption, representing the change in energy consumption. Figure 4 shows the months in which the change in energy consumption was positively marked by the actual energy consumption points below the expected energy consumption, as indicated by the months January, February, May, and July 2020.

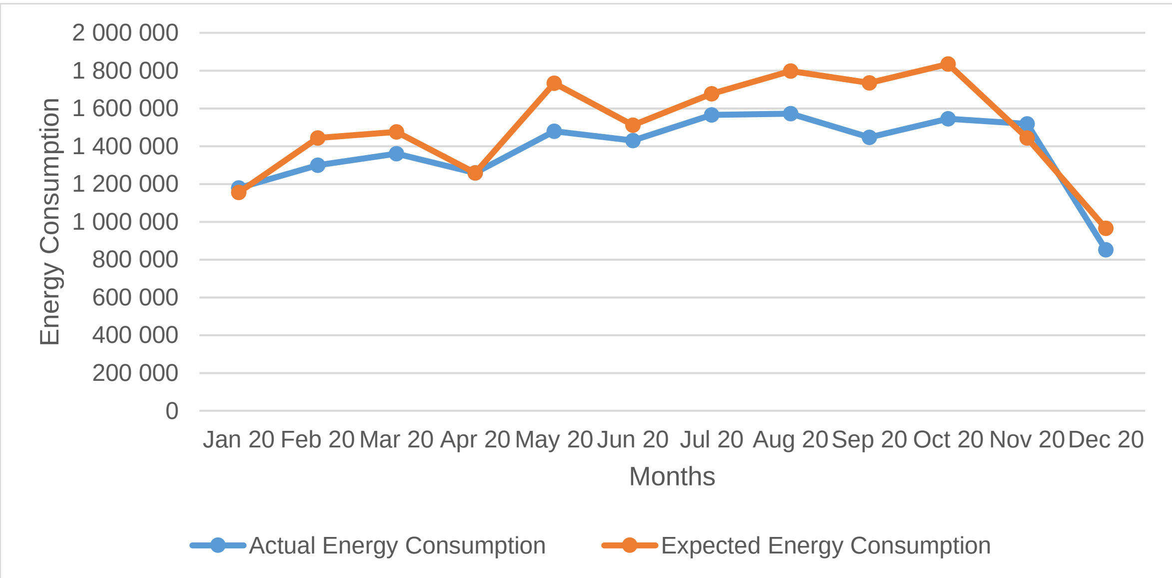

Figure 5: Actual and Expected Energy Consumption for Company B

The monthly change in energy consumption was found to be only different in November 2020, as shown in figure 5 above, where the actual energy consumption was more than expected.

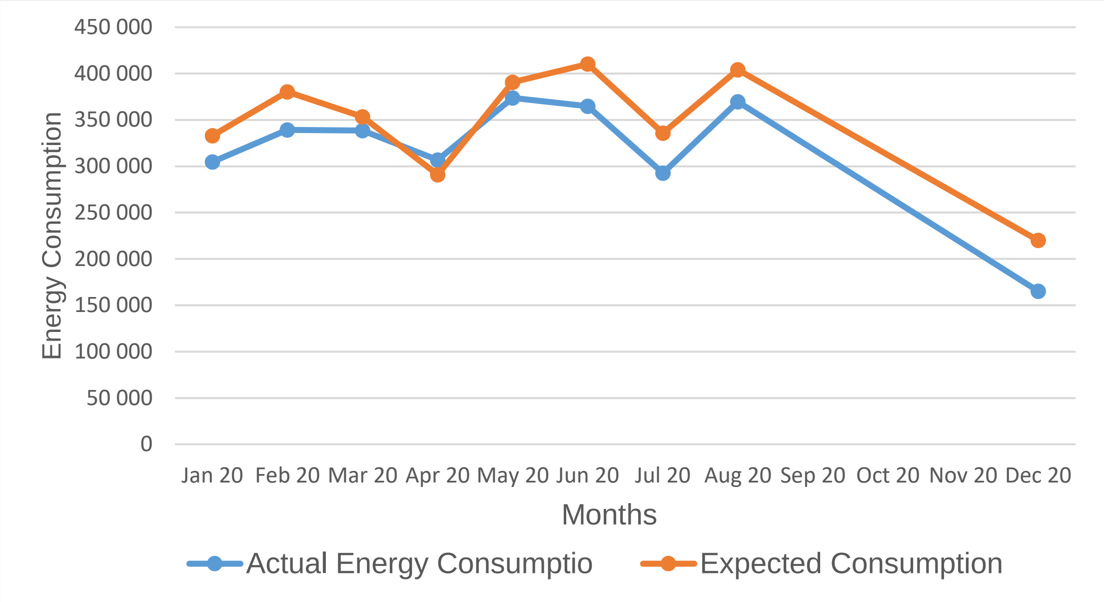

Figure 6: Actual and expected energy consumption for Company C

Figure 6 shows that the monthly change in energy consumption for Company C was the same except in April 2020, when the actual energy consumption was more than the expected energy consumption. The cumulative sum of the overall change in energy consumption for companies A, B, and C resulted in a noticeable annual energy savings of 70 092 kWh, 1528 322.42 kWh, and 262 919 kWh, which represents 0.4%, 10%, and 6% change in energy consumption for companies A, B and C respectively.

4.4. Carbon Tax Savings

The change in energy consumption resulting from RECP project implementation evaluated using the energy baseline models was analysed further to determine the GHG emission equivalent and cost savings in terms of energy and carbon cost saved. This was done by comparing the equivalent GHG emission equivalent of the actual energy consumption after RECP implementation with the GHG emissions equivalent of the resulting energy savings from the implemented projects. Equivalent GHG emissions were determined using the Eskom (2019) electricity convention factor of 1.06 $kgCO_2/kWh$, and carbon costs were calculated using the 2020 carbon tax rate of $R134/tCO_2$. The results are shown in Table 6 below.

The GHG emission equivalent of the resulting change in energy consumption for Companies A and C was 74 tCO_2e and 684 tCO_2e, representing a 0.3% and 4.8% reduction in GHG emission, respectively. These also translate to a carbon tax savings of R 119,882 and R 20,280 calculated at the 2020 carbon tax rate of R134/tCO_2. For company B, the equivalent GHG emissions from the resulting change in energy consumption were found to be 1620 tCO_2e, representing a 10% reduction in GHG emissions compared to baseline GHG emissions of 16184 tCO_2. The reduction in company C's greenhouse gas emissions was calculated to be a carbon tax savings of R 217,080, using the carbon tax rate of R134/tCO_2.

Table 6: GHG emissions, carbon, and energy cost savings

	Company A	**Company B**	**Company C**
Expected Energy (kWh)	16929487	2363901	3055898
Actual Energy (kWh)	16880018	2087291	2855467
Change in Energy (kWh)	70092	1528266	47211
GHG Emission (tCO_2e)	74.3	1620	684
% Savings	0.3	10	4.8
Tax allowance ®	119882	14824	20280
Investment cost ®	3299635	R 258978	308 622
Cost savings ®	282368	R 1 184 039	994 938
Payback (year)	11.7	0.3	0.3

4.5. Interview data

The responses to the interview question of the company managers and the expert consultant (respondent) were analysed to determine whether there is a shared perception and understanding of the implementation of the benefits of the RECP project. The analysis has found that the respondents share the same and different perceptions about certain elements of the implementation of RECP and the benefits thereof (see Table 7 below).

Table 7: List of questions and responses from company managers and expert consultants

QUESTIONS	QUESTIONS AND RESPONSES FROM ALL RESPONDENTS (n=6)			
		YES	PARTIAL	NO
Is your role in RECP implementation also to ensure that data for evaluation, monitoring, and measurements are available?	Q1	6	0	0
Is the data obtained during RECP implementation help in determining the company's consumption pattern	Q2	6	0	0
Is the data obtained during RECP implementation help in determining the company's GHG emissions	Q3	0	6	0
Do the reasons the company participated in RECP implementation include reducing energy consumption, GHG emission, and costs?	Q4	6	0	0
The results achieved include reduced energy consumption, greenhouse gas emissions, and associated costs	Q5	6	0	0
Is the reduced carbon emissions reducing the overall company's carbon tax liabilities?	Q6	3	3	0
Do you see RECP as a tool that offsets carbon tax that any company can implement	Q7	3	3	0
Is the Implementation of RECP projects contributing to all aspects of the company's sustainability?	Q8	6	0	0

Table 7 above shows that all the respondents agreed that their role in RECP implementation ensures that company resource consumption and greenhouse gas emissions data are obtained from all sources during the evaluation, impact monitoring, and measurements phase of RECP implementation. Similarly, all respondents again agreed that the RECP data obtained is useful in determining company resource consumption patterns, which provide the fundamental basis for reporting. Some respondents agreed, and some disagreed that RECP data also determine overall GHG emissions, stating that the scope and limits and the company's areas of concern that RECP assessment strategies focused on resulted in the only focused area (GHG emissions data). This means that it does not always cover all sources of carbon emissions. Hence, the carbon emissions inventory conducted during the RECP assessment does not determine the company's total GHG emissions. Similar responses were obtained from Question 4, which sought to establish the relationship between why companies implement RECP projects and the research objective. It was found that company managers and expert consultants shared the same reason companies implement RECP, which is to reduce resource consumption, equivalent carbon emissions, and associated costs.

All respondents further agreed that the results of the RECP implementation include a reduction in resource consumption, equivalent carbon emissions, and associated costs. But some disagreed that the reduction in carbon emissions from the implementation of RECP can reduce the company's carbon tax liabilities, stating that it depends on the scope of carbon emissions reduced if it is the scope for which the company is currently paying carbon. Similar responses were obtained for Question 7, in that the implementation of the RECP project can be used as a tool to offset or reduce carbon tax. For the same reason as in question 6, All respondents agreed that the implementation of the RECP improves the company's overall sustainability, meaning the benefits realised contribute to reducing the environmental footprint and improving the social and financial aspects of the company.

CHAPTER 5: DISCUSSION AND CONCLUSION

This chapter interprets the research results in line with the research objectives. The research aimed to evaluate the benefits of the implementation of resource-efficient and cleaner production (RECP) implementation to reduce the carbon tax for manufacturing industries by reducing energy consumption, equivalent carbon emissions, and carbon tax, as well as providing the basis for determining energy consumption patterns and GHG emissions for reporting in response to legislative requirements.

5.1. RECP projects implemented

The range of RECP projects implemented varied from behavioural change kind of projects to operational control and equipment modification kind of projects, The behavioural change kind of projects were implemented first and included switching equipment when not in use, especially after shifts, during lunch breaks, and on weekends, when there is no production. These were the most favoured projects implemented in all three sites and have seen the baseload energy for the three sites decrease significantly, which also equates to a reduction in carbon emissions equivalent. These low-hanging fruits of the RECP implementation reduce energy use, carbon emission equivalent, and associated costs. Operational control projects were also among the most implemented projects as they are mostly low-cost projects, and some are part of the plant maintenance. These projects are favoured due to their low investment cost of less than R150,000 and not more than R250,000 and pay-back of less than 3 years. They include setting compressed air at the correct pressure fixing leaks, Geysers, and HVAC systems at the correct temperature. Few projects that required high CAPEX were implemented during scheduled maintenance, like replacing inefficient equipment with energy-efficient ones.

Some high Capex projects that include boiler fuel switching were not yet implemented. These are projects aimed at reducing fuel combustion with higher carbon content, like coal to gas. Most projects these projects require high capital investment were not implemented but deferred to when the CAPEX would be available. These projects are not yet implemented. This would have reduced fuel combustion, the plant, associated emissions, and costs if implemented. These findings were highlighted in Naidu (2020), who indicated that energy efficiency interventions linked to the combustion of coal in a boiler, for example, using alternative fuels in boilers, will also lead to reduced CO2 emissions, thereby contributing to reducing their carbon tax burden.

Projects that involved efficient operating procedures and controls on equipment such as boilers and refrigeration were implemented. Two other projects implemented required high capital investment, but they were part of the scheduled maintenance. The total cost of projects implemented amounted to over Three Million Rands (R3, 299,638). Projects that replaced inefficient equipment with energy-efficient ones (low load profiles) aimed at reducing energy consumption, and the kind of projects aimed to reduce the baseload, the energy used when there is no production, indicate operations that are poorly controlled. The projects implemented included steam systems controls and leak repairs which improved the steam system and reduced the amount of fuel combustion in the boiler system. The cost of implementation represents 11% of the energy costs of the baseline year with a simple payback of 11.7 years.

The findings further show that company B implemented all recommended RECP projects. In total, 13 projects were implemented, of which seven were types of operational control and behavioural change projects which required no capital investment. The other six projects implemented required low-medium capital investment. A total investment cost of more than 2,000 Rands (R 258, 998) was used with a payback time of three months and represented 1.7% of the energy costs of the baseline year. For company C, seven projects were implemented, with a total investment of R 308 622 with a payback time of 4 months. Projects consist of system optimisation and efficient equipment installation to increase operational efficiency and reduce energy wastage when there is no production.

The investment cost of the implemented projects represents 7.5% of the baseline year energy cost. Therefore, it is evident from the RECP projects that, regardless of their investment costs, they address the system inefficiencies identified to result in baseloads, poor operational control that contributed to excess energy use, and equivalent GHG emissions, which increase the carbon tax liability of the companies. The resulting improvement in energy use and equivalent GHG emissions from RECP projects implemented presents an opportunity for companies to reduce their carbon tax through performance allowances. Stojceska, Parker, and Tassou, 2021, highlighted a significant reduction in energy consumption, GHG emission equivalent, and costs (which include energy and GHG emission costs) achieved through implementing an energy efficiency project a Biscuits Industry.

Based on the literature review (Pillay, 2014) and (National Treasury 2019), companies are currently liable for scope one emissions, which are direct emissions from fuel combustion (e.g., Steam production), fugitive emissions like emissions from refrigeration as well as emissions from companies' transport and waste disposal. The RECP Projects implemented resulted in the optimisation of energy systems like boilers and refrigeration systems that subsequently resulted in a reduction of carbon emissions from these systems (boiler and refrigeration), hence reducing the scope 1 emissions of these companies (NCPCSA, 2019). Similar results in the reduction of carbon emissions from coal combustion in a steam system were highlighted by a study in a pulp and paper industry steam system where energy efficiency projects such as optimizing boiler process control, reducing flue gas, and fixing steam leaks during boiler maintenance resulted in 25% of coal and associated emissions (Hilton, 2017). This result supports the findings of this study that improvement in the steam system reduced energy consumption and GHG emission equivalent and scope 1 emission carbon costs.

5.2. Energy use before RECP implementation

The results of the RECP assessment allowed the determination of baseline energy consumption equivalent GHG emissions for companies A, B, and C, which was also translated in terms of carbon costs. This data is required for reporting according to the legislative requirements for the carbon tax to determine future tax-free and performance allowances that the company can qualify for. According to the National Treasury, companies qualify for basic 60% tax-free allowances on their reported annual GHG emissions and a further 5% performance allowance for the annual GHG reduction improvements. The RECP results determined the annual GHG emissions of 29198 tCO_2, 16184 tCO_2, and 4326 tCO_2 for companies A, B, and C, respectively. These data are required by SARS, from the DEA Information system, reported by companies to determine carbon tax liability, including tax-free and performance allowances when GHG emissions reduction improvement is achieved (National Treasury, 2019).

It can be said that the results of the RECP assessment assisted companies in establishing energy baseline models and forecasting future energy consumption for future performance monitoring and measurement. These baseline models have shown a high baseload of 653148 kWh, 41069 kWh, and 85558 kWh for companies A, B, and C, respectively, representing energy used when there is no production, for example, leaving equipment on (compressed air, lights, and HVAC) after production hours. These are operational inefficiencies that can be addressed through a behavioural change in the operating staff and the installation of automated motion sensors to improve energy performance by reducing energy consumption and equivalent greenhouse gas emissions. These findings are in line with those of Kodisang (2016), where some of the benefits of implementing energy efficiency projects in automotive industries were energy baseline improvements through baseload reduction intervention like switching off idle equipment and improving equipment utilization. Rasmeni (2014) also highlighted the resulting potential energy consumption and carbon emission reduction through energy efficiency audits and quick scans in the South Africa Steel Foundry plants.

Establishing an energy baseline model enabled the companies to determine potential energy consumption and equivalent GHG emission reductions from the recommended energy efficiency projects. Company A has a projected energy consumption reduction of 217,206kWh, with equivalent GHG emissions of 230 tCO_2e, which translates to a carbon tax of R29, 240. This represents a 1% reduction compared to the baseline year. This also resulted in an improvement in process efficiency by reducing the baseload. The projected reduction in company B's energy consumption was 477,887kWh, a 3% reduction that converts to 475 tCO_2e and R60, 320 of carbon tax liability.

Company C projected a reduction in energy consumption of 1184500kWh from RECP implementation, representing 10% savings from the baseline year, with an equivalent reduction in GHG emissions of 1256tCO2e, a reduction in carbon cost reduction of R189,457, and energy cost savings of R994,938. It can be said that from the results of the RECP assessment for the three companies, we were able to determine the expected reduction in energy consumption, equivalent GHG emissions, and carbon costs depending on the scope of emissions reduced. These present a baseline to be measured and determine the contribution of the resulting energy savings from RECP projects implementation to GHG emissions and carbon tax reduction. A similar study in the automotive industry has measured the environmental impact of implementing energy efficiency projects in terms of reduction in GHG emissions and associated costs (Kodisang, 2016). However, the associated cost was only limited to energy costs, and the production cost was reduced due to reduced energy consumption. The study was done before the carbon tax was effective. Hence the reduction in GHG emission equivalent was not translated in terms of reducing carbon costs.

5.3. Energy use After Implementation

The assessment of actual energy consumption against the expected energy consumption and equivalent GHG emissions after RECP implementation has shown a change in energy consumption, also known as energy saving in some months and de-saving for a few months. An energy saving is when the actual energy consumption is less than the expected energy consumption, and energy de-saving is when more energy is used after RECP implementation. The cumulative change in energy consumption/ energy savings after the RECP assessment was 70,096 kWh, 1,528,266 kWh, and 645,578kWh for companies A, B, and C, respectively. This reduction in energy use translated into a minimal equivalent of GHG emissions, which equates to carbon cost savings of 0.4 and 6%, especially for companies A and C. The energy savings achieved indicates a significant 10% GHG emissions reduction in carbon cost savings. Companies' change in energy use was measured over a short period of less than a year, based on the number, type, and time projects were implemented. This has resulted in companies realizing minimal change in energy consumption.

These results are similar to those of Matos *et al*. (2018), Kodisang, 2016 and Govender, 2008 that show the contribution of energy efficiency projects implementation in environmental performance improvement through reduced GHG emission equivalent to energy consumption reduction. These were achieved from various energy efficiency projects, like installing efficient lighting (LEDs) and the switch of equipment when not in use, installing VSDs in compressed air systems, upgrading boiler insulation, and fixing boiler insulation leaks. This study has further shown that RECP methodologies provide the basis for companies' GHG emissions inventory for energy sources within the RECP assessment scope and boundary which is regarded as scope two emission "emissions measured from the indirect activities like purchased electricity" (National Treasury, 2018).

The research finding, also supported by Rasmeni and Pan (2014), demonstrated the reduction of CO_2 emissions in foundry industries through the implementation of best energy efficiency practices like maintenance, scrapping off the sand, which improves the charging and melting, good housekeeping, which involves equipment control (for maintaining melting schedules and keeping furnace lid closed), to prevent heat loss and reduce energy consumption, and GHG emissions equivalent which highlights the contribution of efficient use of energy in the climate change mitigation through resulting GHG emission reduction and industrial competitiveness through reduced energy and carbon costs (operational costs). The same results were highlighted by Naidu (2020) that the energy efficiency component has effectively resulted in the AECI Green Gauge achieving energy saving, as well as financial and environmental benefits from the similar energy efficiency project ranging from energy system optimisation, and operational control to housekeeping and behavioural change kind of projects that ensures equipment operate optimally, reduced leaks, and other forms of inefficiencies, which ultimately reduced energy consumption.

5.4. Expert views on RECP

The main objective of conducting the interviews with the company managers and RECP consultants responsible for RECP implementation was to gather their perception and understanding of the RECP process and its benefits for reducing carbon emissions and equivalent carbon tax liabilities. The responses of the company managers and expert consultants (respondents) supported the notion that the main reason industries embark on RECP implementation is to reduce energy consumption, GHG emission equivalent, and costs (operational costs, which include energy costs and carbon costs). They agree that RECP projects are part of their sustainability projects. The respondents further stated that their role supports and ensures energy efficiency project implementation. The response also confirmed that RECP data contribute to the determination of the company's energy consumption patterns, which forms part of the data required for reporting purposes as per the carbon tax legislative requirements.

The respondents share different perceptions on the contribution of RECP data in determining companies' GHG emissions. Some respondents agreed that it determines GHG emissions equivalent (which is scope 2 emissions) to the electricity consumption, and some said it depends on the scope and boundary covered by the RECP assessment, indicating that if the assessment covered all energy sources, all GHG emissions scopes could be determined. This was not the case because data for energy sources that result in scope 1 emissions were not provided during the assessment. From these results, it can be said that the RECP assessment data partially assist companies in determining overall GHG emissions.

The respondent supported RECP implementation to have the potential to reduce energy consumption, equivalent carbon emission, and associated costs. But respondents were not certain about the reduced energy usage' equivalent GHG emissions reducing the carbon tax liabilities of the companies. The reason was that reduced carbon emissions through RECP implementations in their sites mostly relate to scope 2 emissions. Their scope 1 emissions, which include all emissions from fuel (coal) combustion in the steam system, industrial processes, and fugitive emissions, require specialized emissions monitoring system to be determined and the verification of their reduction through RECP projects implemented. Another reason for the certainty in RECP project implemented reducing carbon costs was relating improvement in boiler and refrigeration system through RECP operational control projects implemented, reducing the fuel (coal) combustion in the boiler which reduces the scope 1 emissions which in this could not be quantified as its baseline data was not provided for the study. This was in line with the quantitative findings of the study reduction since the GHG emissions were quantified, as well as the equivalent carbon costs relative to the energy savings achieved.

The research findings also indicate that company managers and expert consultants viewed the general benefits of RECP implementation as improving sustainability through its positive impact on the business's environmental, economic, and social aspects. This supports the implementation of resource-efficient and cleaner production in manufacturing industries, ultimately reducing GHG emissions. It provides a basis for continuous resource monitoring, measurement, and improvement that highlight the manufacturing industry's main goals of sustainability, which include reducing the cost of production, and environmental footprint, and enhancing competitiveness.

What became known from the responses of some company managers is that through RECP implementation, their plants identified all resource efficiency projects that will result in a reduction in all emission scopes (scopes 1, 2, and 3). However, due to the unavailability of CAPEX, the implementation of energy efficiency measures has resulted in a reduction in scope 2 and 3 emissions. The same sentiments were highlighted by the RECP data from the assessments in the form of energy consumption and the recommended RECP projects. RECP projects such as steam system optimisation intervention, improved boiler fuel efficiency, reduced coal combustion, and equivalent GHG emissions were not determined. However, the actual reduction in scope 1 emissions was not determined, as baseline information for coal consumption was not provided for this study, which measures the resulting reduction in GHG emission from coal combustion in the steam system. Similar findings by Naidu, 2020, emphasized the energy savings from energy efficiency projects implemented at various AECI sites, including switching boiler fuel from coal to gas, resulting in reduced GHG emissions and with the actual cost reduction not quantified (carbon costs but not energy cost, as gas, is more expensive than coal). Implemented projects are driven by potential energy savings and are equivalent to GHG emissions.

This study has effectively measured the decrease in GHG emissions equivalent of 0.4%, 4.8%, and 10% for companies A, B, and C, respectively, with the double financial benefit of reduced cost (energy and carbon), compared with the cost for implementation of more than 3 million rands for company A, resulting from few projects implemented, with four more projects still to be implemented. It can be said that the investment cost was higher than the resulting financial benefits. This may have been due to the short monitoring period for savings measurement and losses in energy savings through system inefficiency that has not been addressed by projects that have not yet been implemented. A study by Hilton (2017) has highlighted the same findings in which boiler system efficiency is improved. However, distribution channels are not insulated, leading to heat loss along the way, which reduced savings through increased energy use driven by losses.

The implementation of Company B RECP resulted in remarkable 10% energy savings and reduced equivalent GHG emissions, with all recommended RECP projects implemented at over R250 000 of implementation costs, with financial (energy and carbon costs) higher than implementation cost. This shows that the projects implemented were worth the investment cost. For company B, the resulting GHG emission reduction of 4.8% was achieved with an investment cost of over R300 000, very low compared to the resulting cost savings (energy and carbon costs which supports that the investment cost was worth it. Furthermore, these results also support that RECP implementation in industries can identify energy use and carbon emissions patterns, and find ways to reduce energy consumption, equivalent carbon emissions, and associated cost, which includes a carbon tax.

From the literature review (National Treasury, 2019), the National Greenhouse Gas Emission Reporting Regulation promulgated under the National Environment Management: Air Quality Act of 2004 (Act No.39 of 2004), through the Department of Environmental Affairs, currently known as the Department of Forestry, Fisheries and Environment implements a mandatory Greenhouse gas reporting system for all emission generating facilities to report their emissions, a system that SARS now uses to calculate the carbon tax. It was clear from the responses from company managers that the RECP data primarily feeds into the overall reporting data, which only needs to be verified and provides additional information on the carbon emission reduction targets. This was also supported and shown by the quantitative data from the RECP data, which provided the basis for the establishment of consumption patterns and baseline for determination of potential energy savings and equivalent GHG emissions for reporting according to legislative requirements, which later enables measurement of the actual resulting savings from implemented projects. This enables RECP to be used as a tool to reduce carbon emissions and related costs (carbon tax).

5.5. Research Limitations

As stated in chapter three, the research data were limited to three company data due to the outbreak of the COVID-19 pandemic, which negatively affected some companies that were initially willing to participate in the implementation of RECP. The pandemic has also resulted in most planned RECP project implantations in the three participating companies not being achieved or stopped, limiting data to a few implemented projects. The scope of the RECP was also limited to some plant processes, not at the entire plant level, due to some disruption and lack of data for baseline in some processes. This has led to a GHG inventory of electrical energy from sites and the identification of RECP projects relating to certain processes to improve their electrical energy efficiency. This reduction in scope and data limited the research findings in drawing clear contributions of reduced GHG emissions from RECP implementation in reducing carbon tax. The COVID pandemic has also slowed down research on related topics. This was evident from the lack of related research.

5.6. Recommendation

The quantitative results of the three manufacturing plants have shown the benefits of RECP implementation quantified in the form of a reduction in energy consumption, equivalent cost, and carbon emissions. From the potential financial and operational benefits of all the recommended resource efficiency projects during the RECP assessment and the actual reduction in energy consumption and equivalent carbon emissions evident from the implemented projects, it can be deduced that RECP implementation reduced carbon emissions and the equivalent carbon tax. The research was unable to quantify the carbon tax liability (40% of scope 1 emission) reduced by reducing the carbon emissions from the RECP projects. This was not demonstrated due to the research limitations that resulted in the scope achieved by the research not being sufficient to achieve all data set to demonstrate that reduction in GHG emissions contributes towards an actual reduction in carbon tax. It is therefore recommended that future research should focus on establishing all scope of emissions at the whole-plant level and RECP projects that increase efficient use of energy at the plant level, to be able to clearly show whole-plant baseline emissions before RECP implementation and whole plant reduction in baseline emissions as a result of improved energy efficiency from RECP implementation.

The research has also noted that some projects were not implemented due to a lack of CAPEX. If all recommended projects were implemented, all plant processes would be optimised, resulting in more improved energy efficiency that may have resulted in more direct and indirect GHG emissions reduction. These would have clearly shown a reduction in the carbon tax and show more impact on reduced GHG emissions. Therefore, it is recommended for companies to divert their carbon tax liability budget to implement the RECP project- to reduce their GHG emissions and qualify for an additional 5% tax-free as part of their performance allowance realised from improving operational efficiency, reducing their carbon tax liabilities.

5.7. Conclusion

A conclusion can be drawn from the research findings to the research objective. The research objective was to evaluate the results of RECP implementation in manufacturing plants in reducing the carbon tax. The results of the quantitative data have shown a decrease in carbon emissions of 0.4%, 10%, and 6% for the three manufacturing plants, respectively, from RECP implementation. The reduced carbon emission, in principle, should reduce the equivalent carbon tax. Industries are currently liable to pay tax for scope 1 of carbon emission; only a decrease in carbon emissions that falls under scope 1 emissions will reduce the carbon tax liabilities as part of the additional 5% performance tax-free allowance. The performance allowance seeks to encourage industries to reduce the carbon intensity of their production processes relative to their peers through carbon emission mitigation initiatives like RECP to qualify for a performance allowance of up to five percent of their total emissions.

The research focused on emissions equivalent to the plant's energy consumption, which falls under scope 2 emissions. However, the implementation of RECP improved the energy systems that burn fuel, like coal boilers, and releases scope 1 emission. This has shown an indirect contribution to a carbon tax reduction from RECP implementation,

The research also aimed to determine the contribution of RECP implementation results in assisting manufacturing plants in measuring carbon emissions for reporting in response to the legislative requirement. The results of qualitative data have indicated that company managers and expert consultants believe that data collected during the RECP assessment phase assist companies in determining their energy consumption patterns and equivalent carbon emissions, which form the basis of their data for reporting. The results of the quantitative data have also enabled the establishment of energy consumption baselines and patterns, as well as their equivalent carbon emissions. Additionally, companies have realised a reduction in energy consumption and equivalent carbon emissions from the RECP implementation, which can be used to report a reduction in GHG emissions for carbon tax performance allowances. The Carbon Tax in phase 1 (June 2019- December 2022) was set at a very low effective carbon tax rate with significant tax-free emission allowances ranging from 60 percent to 95 percent on the basis that emitters will have time to transition their operations to cleaner technologies through investments in energy efficiency, renewables, and other low-carbon measures (National Treasury, 2019). With Phase 2 of the Carbon tax coming in January 2023, more scope of emissions may be covered by the carbon tax, which RECP implementation may contribute significantly to reducing carbon tax for industries.

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Annexure

A: Ethics Clearance

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF ANIMAL, PLANT AND ENVIRONMENTAL SCIENCES ETHICS COMMITTEE
CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: HA2005**
PROJECT TITLE	Implementing Resource Efficient and Cleaner Production as a tool to reduce carbon tax in the Manufacturing Industries
INVESTIGATOR	Ms Phathutshedzo Ndifelani Maggie Mashau
SCHOOL/DEPARTMENT OF INVESTIGATOR	School of Animal, Plant and Environmental Sciences
DATE CONSIDERED	19 March 2021
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	MINIMAL RISK
EXPIRY DATE	Date of submission of the project Research Report

ISSUE DATE OF CERTIFICATE 26 March 2021 **CHAIRPERSON** ______ ____________________
(Dr Shalini Dukhan)

cc: Supervisor: Dr Ute Schwaibold

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

I fully understand the conditions under which I am are authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

________________________ **31__/__03___/___2021___**
Signature **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

B: Energy consumption and production data

Company A Energy Consumption Analysis									
Date	**Energy (kWh)**	**Production (tonnes)**	**Energy Cost ®**	**CO_2e(t/kWh)**	**CO_2e®**	**SEC- (kWh/t)**	**Expected Energy (kWh)**	**Actual-Expected**	**CO_2e (t/kWh)**
Jan 19	2 010 049	1 499 247	R1 487 965	2 131	R270 593	1.3			
Feb 19	2 190 230	1 545 035	R1 611 255	2 322	R294 849	1.4			
Mar 19	2 322 930	1 475 138	R2 232 078	2 462	R312 713	1.6			
Apr 19	2 033 596	1 230 761	R2 335 106	2 156	R273 763	1.7			
May 19	2 412 474	1 508 390	R2 089 499	2 557	R324 767	1.6			
Jun 19	2 233 265	1 524 451	R2 447 535	2 367	R300 642	1.5			
Jul 19	2 249 986	1 524 942	R3 837 535	2 385	R302 893	1.5			
Aug 19	2 157 173	1 603 035	R3 359 218		R290 399	1.3			
Sep 19	1 959 655	1 259 599	R3 239 941	2 077	R263 809	1.6			
Oct 19	2 106 037	1 373 543	R1 979 397	2 232	R283 515	1.5			
Nov 19	2 273 793	1 593 446	R2 123 337	2 410	R306 098	1.4			
Dec 19	784 545	167 003	R2 242 224	832	R105 615	4.7			
Jan 20	1 978 845	1 334 401	R1 058 338	2 098	R266 392	1.5	2 035 947	-57 102	2 158
Feb 20	2 185 149	1 454 454	R1 992 633	2 316	R294 165	1.5	2 160 355	24 794	2 290
Mar 20	2 322 321	1 442 720	R1 731 264	2 462	R312 631	1.6	2 148 195	174 125	2 277
Apr 20	2 016 250	1 322 722	R1 587 266	2 137	R271 428	1.5	2 023 845	-7 595	2 145
May 20	2 222 080	1 666 685	R2 000 022	2 355	R299 136	1.3	2 380 283	-158 204	2 523
Jun 20	1 961 242	1 443 395	R1 732 074	2 079	R264 022	1.4	2 148 895	-187 652	2 278
Jul 20	2 084 151	1 427 832	R1 713 398	2 209	R280 568	1.5	2 132 767	-48 616	2 261
Aug 20	2 109 979	1 202 441	R1 442 929	2 237	R284 045	1.8	1 899 201	210 778	2 013
Sep 20	1 963 693	1 226 275	R1 471 530	2 082	R264 352	1.6	1 923 900	39 793	2 039
Oct 20	1 737 042	1 104 256	R1 325 107	1 841	R233 841	1.6	1 797 455	-60 414	1 905
						Energy Cons reduction		**-70 092**	**0.4%**

Company B Energy Consumption Analysis										
Date	**Energy Consumption (kWh)**	**Production (tonnes)**	**Energy Cost ®**	**CO_2e(t/kWh)**	**CO_2e®**	**SEC (kWh/t)**	**Expected Energy Consumption**	**Actual-Expected (kWh)**	**CO_2e (t/kWh)**
Jan 19	1 111 036	111 494	R1 344 353	1 178	R149 568	9.96			
Feb 19	1 215 861	150 225	R1 471 192	1 289	R163 679	8.09			
Mar 19	1 299 290	144 779	R1 572 141	1 377	R174 910	8.97			
Apr 19	1 054 145	101 037	R1 275 515	1 117	R141 909	10.43			
May 19	1 385 521	150 733	R1 676 481	1 469	R186 519	9.19			
Jun 19	1 343 165	143 821	R1 625 230	1 424	R180 817	9.34			
Jul 19	1 406 231	154 341	R1 701 539	1 491	R189 307	9.11			
Aug 19	1 450 148	149 250	R1 754 679	1 537	R195 219	9.72			
Sep 19	1 324 719	135 867	R1 602 910	1 404	R178 334	9.75			
Oct 19	1 412 543	144 918	R1 709 177	1 497	R190 157	9.75			
Nov 19	1 383 931	173 768	R1 674 556	1 467	R186 305	7.96			
Dec 19	881 651	86 668	R1 066 797	935	R118 688	10.17			
Jan 20	1 178 666	118 552	R1 426 186	1 249	R158 672	9.94	1 155 011	23 654.98	353
Feb 20	1 299 201	164 496	R1 572 033	1 377	R174 898	7.90	1 443 467	-144 266.10	403
Mar 20	1 361 235	169 758	R1 647 094	1 443	R183 249	8.02	1 476 504	-115 269.13	375
Apr 20	1 257 899	135 106	R1 522 058	1 333	R169 338	9.31	1 258 944	-1 045.01	308
May 20	1 479 876	210 795	R1 790 650	1 569	R199 221	7.02	1 734 152	- 254 275.92	414
Jun 20	1 430 769	175 323	R1 731 230	1 517	R192 610	8.16	1 511 444	- 80 675.03	435
Jul 20	1 565 413	201 743	R1 894 150	1 659	R210 736	7.76	1 677 320	- 111 906.54	356
Aug 20	1 572 066	220 890	R1 902 200	1 666	R211 632	7.12	1 797 533	- 225 466.79	428
Sep 20	1 446 360	211 029	R1 750 096	1 533	R194 709	6.85	1 735 621	- 289 261.07	233
Oct 20	1 544 519	226 795	R1 868 868	1 637	R207 923	6.81	1 834 607	- 290 087.56	353
Nov 20	1 517 382	164 496	R1 836 032	1 608	R204 270	9.22	1 443 467	73 914.75	403
Dec 20	851 487	88 308	R1 030 300	903	R114 627	9.64	965 126	- 113 639.01	375
							Energy Saving	**-1528 322.42**	**10%**

Company C Energy Consumption Analysis									
Date	Energy (kWh)	Production (tonnes)	Energy Cost ®	CO_2e(t/kWh)	CO_2e®	SEC (kWh/t)	Expected Energy (kWh)	Actual-Expected (kWh)	
Jan 19	290 403	121 800	R389 140	308	R39 094.07	2.4			
Feb 19	358 735	151 000	R480 704	380	R48 292.85	2.4			
Mar 19	369 223	152 869	R494 758	391	R49 704.75	2.4			
Apr 19	282 466	115 860	R378 505	299	R38 025.62	2.4			
May 19	315 717	106 090	R423 060	335	R42 501.79	3.0			
Jun 19	371 655	148 224	R498 018	394	R50 032.22	2.5			
Jul 19	355 337	152 630	R476 152	377	R47 835.52	2.3			
Aug 19	378 149	161 003	R506 720	401	R50 906.46	2.3			
Sep 19	376 246	163 109	R504 170	399	R50 650.24	2.3			
Oct 19	371 576	175 155	R497 912	394	R50 021.58	2.1			
Nov 19	407 904	154 766	R546 591	432	R54 912.04	2.6			
Dec 19	204 130	75 698	R273 534	216	R27 479.95	2.7			
Jan 20	304 831	135 897	R408 474	323	R41 036.39	2.2	332 932	-28 101	353
Feb 20	339 133	161 884	R454 439	359	R45 654.15	2.1	380 236	-41 103	403
Mar 20	338 570	147 179	R453 684	359	R45 578.33	2.3	353 469	-14 899	375
Apr 20	306 802	112 792	R411 115	325	R41 301.71	2.7	290 874	15 928	308
May 20	373 765	167 601	R500 846	396	R50 316.30	2.2	390 643	-16 878	414
Jun 20	364 738	178 377	R488 749	387	R49 101.03	2.0	410 259	-45 521	435
Jul 20	292 757	137 436	R392 294	310	R39 410.91	2.1	335 734	-42 977	356
Aug 20	369 604	175 061	R495 269	392	R49 756.09	2.1	404 223	-34 619	428
Dec 20	165 266	73 866	R221 456	175	R22 248.05	2.2	220 017	-54 751	233
						Energy Cons Reduction		**-262 919**	**6%**

C: Regression analysis summary

Company A Regression Analysis Summary Output

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.963679054							
R Square	0.928677319							
Adjusted R Sc	0.921545051							
Standard Errc	118647.7032							
Observations	12							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	1.83E+12	1.83E+12	130.20785	4.68342E-07			
Residual	10	1.41E+11	1.41E+10					
Total	11	1.97E+12						
	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	653147.5102	128056.3	5.100471	0.0004637	367820.2803	938474.7	367820.3	938474.7
Production (t	1.036270315	0.090814	11.41087	4.683E-07	0.833923339	1.238617	0.833923	1.238617

Company B Regression Analysis Summary Output

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.898893543							
R Square	0.808009602							
Adjusted R Squa	0.788810563							
Standard Error	79886.43885							
Observations	12							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	2.69E+11	2.69E+11	42.08593827	7.0068E-05			
Residual	10	6.38E+10	6.38E+09					
Total	11	3.32E+11						
	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	410690.9241	134808.7	3.046471	0.012325699	110318.375	711063.5	110318.4	711063.5
Production (ton	6.278427581	0.967793	6.487368	7.00681E-05	4.12205086	8.434804	4.122051	8.434804

Company C Regression Analysis Summary Output

SUMMARY OUTPUT									
Regression Statistics									
Multiple R	0.921889169								
R Square	0.84987964								
Adjusted R Square	0.834867604								
Standard Error	23130.54957								
Observations	12								
ANOVA									
	df	*SS*	*MS*	*F*	*Significance F*				
Regression	1	3.03E+10	3.03E+10	56.61321626	2.0064E-05				
Residual	10	5.35E+09	5.35E+08						
Total	11	3.56E+10							
	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*	
Intercept	85558.2625	34486.22	2.48094	0.032490465	8718.16608	162398.4	8718.166	162398.36	
Production (tonnes)	1.820304306	0.241927	7.524175	2.00638E-05	1.28125644	2.359352	1.281256	2.3593522	

C: Interview Questions and responses

INTERVIEW QUESTIONS AND RESPONSES			
Questions	**Response from Manager A**	**Response from Manager B**	**Response From Manager C**
What is your role in your company regarding RECP implementation?	Ensure RECP Implementation is rolled out in the entire facility, ensure RECP reports and recommendation that comes through and we draw up action plan	Craft /drive sustainability strategies which RECP fit well into	Responsible for identification of areas of inefficiencies, determining the resource consumption patterns Ensure RECP strategies identified are implemented Drive awareness in the company
What have you done so far to ensure that your company implements RECP policies?	Set up budget and ensure capex to be improved by the board, also I ensure interventions that do require capital are implemented first	Raise awareness internally to all stuff Attended RECP trainings and implement no-cost RECP Projects	Training of staff, assessment audit, and awareness raising about areas of inefficiencies Presentation of business case for capex
What would you say are the main reasons your company Implemented RECP Projects?	-Obtain solutions: to save resources and ensure environmental compliance	Industry experts pick up areas company may be blind-in RECP picks up projects that are an element of business environment stewardship. RECP provide full holistic view in achieving sustainability	Sustainability, it has been identified as a tool to address inefficiencies, trained to be experts to roll it out in other reduce cost and energy emissions., load shading, cost of energy and climate change
What are the benefits of RECP implementation? Has your company been able to measure the results of your implementation of resource efficiency projects? (Please elaborate.)	Financial and environmental savings- due to reduced GHG emissions (Water, steam, and Energy)	Looks at kWh/ton of products Decline in the Environmental Metrix- reduction, emission, and energy and water efficiency of greenhouse gases.	Improvement in the steam system and realising Steam savings. Identified energy bills discrepancies and the need water monitoring- became aware of the plant’s consumption
Has your company been able to quantify and sustain savings from your implemented resource efficiency projects? (How are you ensuring that it keeps going?) Are there challenges in implementing RECP? (Please elaborate)	Reduction in carbon and costs Improvement can be quantified. Savings are sustainable Challenges is budget- capex	Where there is metering, savings are easily quantified, bills also provides a clear decrease in consumption. Savings data are always validated and measured to demonstrate the impact.	Yes, through CUSUM as performance indicator- issues with boiler, also due to base year, No, for only that period of implementation, yes, for 2020. Lack of buy-in by all personnel in the company, especially the ones that

		Continuous training of new team, ensure the projects implemented are sustainable Management buy-in, operation discipline, remunerating the team remuneration drives the sustainability of the gained savings. Challenges- making RECP the way of business not an initiative Being treated as a programme, find people not prioritizing, not involving the right people, lack of the right tools and resources. Budget and right motivation	drives resource consumption in the plant
Based on the cost-benefit analysis of the implementation of RECP, is it worth it?	Yes, it.it is worth it Get to work with team of experts and attain solution	Yes, - Looking at it from the long-term value perspective	Yes. Investment cost is less than the resulting savings benefits
How is your company responding to Carbon Tax legislative requirement (measuring and reporting energy consumption and carbon emissions?	The table of the RECP report if recommendation provides information on the consumption and carbon emissions savings from the recommended projects	We have been reporting on GHG performance- continuously calculating based on 120/ton, to plan around reducing GHG emissions.it was 68mil- when we started and now it has been reduced to 18mil Small boiler (10t). Data analysis and reporting are done internal using correct emission factor only and verified externally Yes, RECP reports provide a calculated reduction from implementation of RECP projects	Have Pollution prevention Plans and target initiative that ensures that measuring and reporting on GHG emissions is done. Yes, RECP implementation is effective in monitoring, measuring resource consumption since data identified feeds into the pollution prevention plan, quantify them- links directly and it Keeps you on checking,
What projects are you implementing to reduce carbon emissions?	Yes, the efficiency of the steam system resulted in lots of savings	Lighting and changing refrigerant Boiler efficiency and coal Even some scope 3 emissions- around transport, we have done some	Solar PV, drive boiler efficiency and fuel switch from coal to gas

Are the RECP strategies your company has implemented effective in measuring carbon emissions?	Yes, Report on emissions quarterly, get data verified, and provide info to the tax team to report. Ensure monthly reporting – measure are in-place	Yes, reports provide additional information on reduced GHG emissions	Yes, it feeds into the reporting template.
What are the advantages and disadvantages has your company experienced in attaining your intended results from RECP Implementation?	Steams/ boilers efficiency Better usage of coal All energy efficient Most of these projects were identified through RECP assessment Reducing GHG emissions through quick wins identified from RECP done by experts and not bias Financial constraints		
What is your take on carbon offset? And resource efficiency projects in reducing carbon tax for your organisation?	Carbon tax is still new; we look forward to find opportunities from carbon offset projects	Some are long-term benefits not credited sufficiently- reforestation and food gardens- they have their disadvantages, but not yet enough. Energy efficiency projects like biogas and renewable projects- it does not deserve the proper attention. And due to costs associated. Yes, the reduction in GHG emissions, but its impact on the carbon tax maybe minimal	The legislation is not yet clear about offset reducing tax liability, and it is also not the first option to reduce their companies for carbon tax liabilities, the company may rather use the tax benefits from efficiency projects than carbon offset
Which projects can you recommend companies to implement to offset their carbon tax?	Not yet sure, not enough. Changes in demand, increases in emissions Not adequate to reduce the carbon tax.	RECP has helped us reduce our liability, other offset projects are capital-intensive and doesn't provide that credit- Projects that will make business sense and align with the company's goals or vision	Solar Photovoltaic Implementation Decarbonization - switching of fuel to gas- move away from coal. Replacement with gas boilers. Waste to energy projects.

Expert Consultants' Response			
Questions	**Response from Consultant A**	**Response from Consultant B**	**Response from Consultant C**
What is your role as consultant in RECP Implementation?	Assessor and training, raise awareness	Provides training to the company to raise awareness and obtain management approval. Conduct an assessment.	Assist industries understand the RECP concept and changing efforts Focus on innovation- operation changes that will lead to sustainability in the organisation
What does RECP mean to you as a consultant assisting industries?	Resource Efficiency- means to achieve more production while using less resources- water energy and material to realise long-term benefit of sustainability and to respond to climate change- Improve effects of climate change. Profits are short-term benefits- profits	You can no manage what you don't know, What would you say are the main reasons industries implement Resource Efficiency projects? Makes financial sense- feasible because costs of resources	Using the resources more sustainably-
What would you say are the main reasons industries implement Resource Efficiency projects?	Sustainability, cost of electricity has triples- managing resources efficiently will preserve/conserve resources – create capacity and reduce effects of climate change Increase in global competition-	Makes financial sense- feasible because costs of resources	Education- within the organisation- key technical stuff Improve operational efficiency. Sustainability is a factor of 3 forces- financial, natural, and social capital- how they work together to benefit the organisation.
What are the benefits of implementing RECP strategies?	Increase profits and reduce carbon emissions. Awareness of true costs of resources, production, and waste-quantifying this makes industries realise more benefits- better understanding of processes, more innovation.	Saves money and the environment, reduces liability and improves image, awareness of resources costs and consumption, think of less waste.	Benefits differs per organisation. Financial –Profits Natural resources efficient/less resources (energy, water and material) Environmental – reducing carbon and waste
Have you managed to quantify the implementation results of the resource efficiency projects? (Please elaborate.)	Some are possible to quantify, kWh and kl and carbon emissions saved Baseline not defined makes it difficult to quantify resulting savings of the implementation The parameters that affect consumption have changed	Follow-ups, yes, its quantifiable, track changes, things have changed.	Not effectively due to loophole in the matrix- needs attention. Greater understanding of achieving change. Verification of changes needs to be put in place-

	No resources to measure post implementation		Errors in billing makes it not easy to quantify results- but calibrated meters come in handy
Are there challenges in implementing RECP? (Please elaborate)	Lack of knowledge in industries-focus on production output not methodology-companies do not look at the processes to improve. Revenue-cost of production+ production Controlling production will impact on costs Attitude to change	Commitment of the rest of the organisation, it takes time, behavioral change- takes time. Knowledge and skills gap- lack of capacity & finances.	Change- Lack of education and knowledge Lack of implementation measurement Financial, not taking risks Behavioral change not easy
Would you advise other manufacturing plants to implement RECP? What would be your reasons?	Yes, u can control cost, but you cannot control the market, improve profitability	Yes, continuous improvement	
With carbon tax effective form June 2019. Qualifying companies are required to measure and report their carbon emissions. Is the outcomes of RECP strategies implementation have any contribution in your business's response to carbon tax legislative requirements (measuring and reporting carbon emissions)?	Lays the groundwork- by understanding where you are consuming and how much you are emitting. In the end calculating the carbon tax. RECP helps industries understand their processes better	Yes, how to reduce carbo- footprint Reducing and Optimizing	Yes, RECP Assessments data provides some information for reporting
Is there a service you are offering to assist industries to respond to carbon tax legislative requirement by submitting energy management plans, measuring, and reporting carbon emission?	No	Yes- carbon Foot-printing.	Measuring and reporting Showing offset
What are the outcomes of RECP projects that are effective in measuring carbon emissions?	Energy—to measure electricity, carbon emission calculations is based on electricity consumption Which projects can you advise the industries to embark on to reduce carbon emissions?	Yes, additional information, installed thermal capacity of scope 2 and 3.	Yes

	It depends on company, focus on consumption of fossil fuel Reduce wastages before opting for alternative energy		
What is your take on carbon offset and resource efficiency projects implemented as carbon offset projects? (Please provide more details).	In SA, somewhere to go, offset mechanism. Cost of implementation of projects is less. system in-place,	7 refrigerants yes, RECP improvement on carbon footprint	Energy Efficiency - Mining Depends on industry where it can make a difference Not sufficient HVAC- Alternative energy projects
Which projects can you recommend to companies you are working with to implement to offset their carbon tax?	RECP Reduces carbon emission and liability for carbon tax if you are above the threshold. Carbon tax is trying to encourage companies to reduce or use less resources- and RECP does that		Solar PV. Heat Pump, Compressed and steam optimisation

D: Plagiarism Declaration

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Animal, Plant and Environmental Sciences

SENATE PLAGIARISM POLICY

Declaration by students

I, Phathutshedzo Ndifelani Maggie Matumba (Student number: 878251), a student registered for Masters Environmental Science in the year 2022. I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or acknowledging the original source) is wrong.
- I have read and understood the document containing plagiarism guidelines for students in the School of Animal, Plant and Environmental Sciences.
- I confirm that the work submitted for assessment for the above course is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.

Signature: Matumba Date: 04/10/2022