A CASE STUDY TO ASSESS THE BENEFITS OF IMPLEMENTING ENERGY EFFICIENCY PROJECTS AS PERCEIVED BY THREE AUTOMOTIVE COMPONENT MANUFACTURERS IN THE NELSON MANDELA BAY MUNICIPALITY

by

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Submitted in Accordance with the requirements for the degree

MASTER OF SCIENCE

in the subject of

ENVIRONMENTAL MANAGEMENT

at the

DEPARTMENT OF ENVIRONMENTAL SCIENCE

UNIVERSITY OF SOUTH AFRICA

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SEPTEMBER 2016

DECLARATION

I, Thembi Kodisang Sibanda (ID number 8112300662082) declare that this dissertation entitled: “A CASE STUDY TO ASSESS THE BENEFITS OF IMPLEMENTING ENERGY EFFICIENCY PROJECTS AS PERCEIVED BY THREE AUTOMOTIVE COMPONENT MANUFACTURERS IN THE NELSON MANDELA BAY MUNICIPALITY” is my own work, and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references. Prior to the commencement of the research project, both the researcher and the UNISA library conducted a literature review, and ascertained that no other similar research had been conducted in South Africa, prior to the registration of this project.

Signature:___________________________ Date:____________________

ACKNOWLEDGEMENTS

I would like to acknowledge the following people and organisations for their contributions to this dissertation:

- God, for His sufficient grace, wisdom, provision and strength.
- CSIR and NCPC, for providing financial support and the opportunity to further my studies.
- My supervisors, Prof. Nel and Prof. Hendrick, thank you for your wisdom, guidance and patience with me. Your time and guidance I truly appreciate, and I am grateful for the blessing of having these two wise men who continued to encourage me during this life-changing season in my life.
- To the companies that allowed me to do my research, and the company representatives – I thank you.
- Mrs Leslie Adriaanse, for your support and time, I appreciate you - best librarian.
- Mr Munyaradzi Makumbe, for your technical energy support.
- Energy consultants for the energy assessments, Ideaxion Africa and Triple Point, I thank you.
- Mrs Ntina Mauke, for statistics support.
- Mrs Marlette van der Merwe, for your editing support.
- To my husband, thank you for your love, encouragement and support.
- My dear mother, I am grateful to you for standing in the gap for me through your prayers.

Thank you all for believing and being part of Team Thembi.

ABSTRACT

Increasing energy efficiency is critical towards mitigating greenhouse gas emissions from fossil-fuel combustion, reducing oil dependence, and achieving a sustainable global energy system (Greene, 2011:608). Most South African legislation and research scholars support the above statement; however, with a lack of tangible evidence, the statement is yet to be proved physically true in the South African manufacturing industry.

A case study was conducted within three automotive component manufacturers located in Nelson Mandela Bay Metropolitan Municipality, with the objective of identifying energy efficiency projects; investigate the perception of company employees on energy efficiency and assessing whether there are benefits for the companies when implementing such projects. For the research methodology, the mixed mode method was used. Quantitative data was collected using energy assessments and a questionnaire was used for the collection of qualitative data. The quantitative and qualitative findings clearly demonstrate that company managers and operational staff need to have a clear understanding of the concept of 'energy efficiency'. Efficiency projects implemented include automated compressors, changing hot-water geyser settings, installation of power factor correction, and tariff structure changes.

The quantitative recommendations were centered on switching off equipment when not required. As an alternative, the use of sensors, timers and other automated control devices should be investigated and implemented where feasible. Qualitatively recommendations advise that companies with employees who do not understand energy efficiency, training and awareness programmes need to be applied. Employees would then be able to put their energy saving knowledge into action. This study demonstrated that there is a need for further research to be undertaken, to improve efficiency for energy within the automotive manufacturing industry.

Keywords: Automotive component manufacturers, carbon footprint, efficiency projects, energy, energy efficiency, energy model.

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ABBREVIATIONS AND ACRONYMS

CAES:	College of Agriculture and Environmental Sciences
CMP:	Meeting of the Parties at COP17
CO_2:	Carbon dioxide
COP17:	The 17th Conference of the Parties
CSIR:	Council for Scientific and Industrial Research
DME:	Department of Minerals and Energy
DTI:	Department of Trade and Industry
EE:	Energy Efficiency
EECA:	Energy Efficiency and Conservation Authority
ESKOM:	Electricity Supply Commission
G8:	The Group of Eight
GDP:	Gross Domestic Product
GEEF:	Green Energy Efficiency Fund
GHG:	Greenhouse gas
MCEP:	Manufacturing Competitiveness Enhancement Programme
MOA:	Memorandum of Agreement
NCPC-SA:	National Cleaner Production Centre of South Africa
NMBMM:	Nelson Mandela Bay Metropolitan Municipality
NO_X:	Nitrogen oxides
IEE:	Industrial Energy Efficiency Improvement Project in South Africa
IPAP:	Industrial Policy Action Plan
OECD:	Organization for Economic Cooperation and Development
RECP:	Resource Efficiency and Cleaner Production
SANEDI:	South African National Energy Development Institute
SMEs:	Small and Medium Enterprises
SO_2:	Sulphur dioxide
TPES:	Total primary energy supply
UN:	United Nations
UNFCCC:	United Nations Framework Convention on Climate Change
UNICED:	United Nations Conference on Environment and Development

UNIDO:	United Nations Industrial Development Organization
UNISA:	University of South Africa
VSD:	Variable speed drive

GLOSSARY

Automotive component manufacturers: The respondent population is defined as automotive suppliers of the following parts:
- Individual parts: generic individual components or groups of non-assembled components (e.g. batteries, belts, gears, hinges, pistons, pumps, locks, seals, tyres, fasteners, cables);
- Assembled units: generally these are parts of a larger subsystem (e.g. air bags, disc brake callipers, seat frames, small motors, windshield wipers, fans, lamps) (Liker, Rajan, Kamath, Wasti & Nagamachi, 1996:67).

Carbon footprint: The amount of CO_2 and other greenhouse gases emitted over the full life cycle of a production process (Rizet, Browne, Cornélis & Léonardi, 2010:10).

Effectiveness: Effectiveness is inclusive of efficiency. Being effective is about doing the right things, while being efficient is about doing things right (Goh, 2013).

Efficiency projects: Efficiency improvement opportunities for achieving the energy-saving targets (Shen, Price & Lu, 2012:346). (For this research, the opportunities include automated compressors, changing hot-water geyser settings, implementing daylight harvesting, installing VSD-controlled compressors, and installing power factor correction).

Eigenvalues: Eigenvalues are a special setoff scalars associated with linear system of equations (i.e a matrix equation) that are sometimes also known as characteristic roots, characteristic values, proper values or latent roots (Wolfram, 2016).

Energy: Electricity, produced by Eskom, the national electricity provider, and produced from coal (Inglesi-Lotz & Pouris, 2012:4779). (For this study, all other forms of energy are excluded – such as petroleum).

Energy assessments: The procedure by means of which it is possible to analyse the energy balance of a system, in order to define possible improvements of its energy efficiency, to achieve the mitigation of its environmental impact, and to reduce energy costs (Dongellini, Marinosci & Morini, 2014:425).

Energy efficiency: Enhancing continuous production processes to reduce energy use, increasing recovery of waste energy and process gases, and efficient design of electric systems – for example, compressed air systems, pump systems, fan systems and motor systems. The potential for energy efficiency improvement varies, based on the production route used, energy intensities of electricity, and the boundaries chosen for the evaluation (Worrell, Bernstein, Roy, Price & Harnisch, 2009:113).

Energy intensity: Energy intensity of the process is expressed using electricity intensity, final energy intensity, and primary energy intensity (Kong, Price, Hasanbeigi, Lui & Li, 2013:1335).

Energy model: Means of which the energy balance of the site is analysed by the impact of various energy-saving actions on the primary energy consumption of the site (Dongellini *et al.*, 2014:4233).

Factor analysis: Factor analysis is a useful tool for investigating variable relationships for complex concepts such as socioeconomic status, dietary patterns, or psychological scales. It allows the researcher to investigate concepts that are not easily measured directly by collapsing a large number of variables into few interpretable underlying factors. (Rahn, 2012).

Chapter 1

Introduction

1.1 Background

Traditionally, electricity costs in manufacturing have been considered as an overhead cost. Over the past decade, the manufacturing industry has witnessed a dramatic increase in the cost of electricity. This can no longer be treated as an overhead, but as a valuable resource to be managed strategically (Kara, Bogdanski & Li, 2011:4).

Salonitis and Ball (2013:634) explain that energy efficiency is one of the key drivers of sustainability. Within manufacturing environments, energy efficiency importance has grown, and it is now considered to rank among other decision-making factors such as productivity, cost and flexibility. In addition, Inglesi-Lotz and Pouris (2012:114) define energy efficiency as the ratio between energy consumption and economic output. In other words, the value of energy intensity shows how many units of energy are consumed for the production of one unit of economic output.

Equally importantly, Patterson (1996:377) describes energy efficiency as using less energy to produce the same amount of services or useful output. For example, in the industrial sector, energy efficiency can be measured by the amount of energy required to produce a tonne of product; hence, energy efficiency is often broadly defined by the following simple ratio:

$$\frac{\text{Useful output of a process}}{\text{Energy input into a process}}$$

For this research, Patterson's definition of energy efficiency will be used.

Bunse, Vodicka, Schönsleben, Brülhart and Ernst (2011:667) state that for governments and manufacturing companies, global warming, rising energy prices and customers' increasing ecological awareness have pushed energy-efficient manufacturing to the top of the agenda. Additionally, governments and companies are both striving to identify the most effective measures to increase energy efficiency in industrial companies' manufacturing processes, for integration of energy efficiency performance in production management. Uniquely, energy efficiency has a key role to play in arresting climate change (Ürge-Vorsatz & Metz, 2009:89).

The Kyoto Protocol of 1997 is an agreement under which industrialised countries (Annex 1 countries) would reduce their combined greenhouse gas (GHG) emissions by at least 5%, compared with 1990 levels, by the period 2008 to 2012. Following ratification by Russia, the United Nations Protocol became legally binding on 16 February 2005, thereby committing the Annex 1 parties, accounting for 61,6% of the total 1990 carbon dioxide emissions, to achieve the 5% reduction by 2012.

South Africa acceded to the Kyoto Protocol in March 2002. Although the Protocol did not commit the non-Annex 1 (developing) countries, such as South Africa, to any quantified emission targets in the first commitment period (2008 to 2012), there was a potential for low-cost emission reduction options in these countries (DME, 2005:9).

Within the United Nations Convention on Climate Change (UNFCCC), South Africa is a non-Annex I country (developing country) and a signatory to the Kyoto Protocol. South Africa ratified the Protocol on 31 July 2002, but, as a developing country, it does not have targets under the Protocol (European Commission, 2016).

In early 2007, South Africa was plunged into darkness, as the grid ran up against capacity limitations. The crisis resulted in immediate mandatory electricity rationing for the country's large power users, together with discussions on ongoing energy efficiency measures, and the need for a proper planning process for capacity investment (Tyler, 2010:580).

Industrial demand has been the major source of recent increases in energy demand across all energy carriers. Some growth can be seen in the transport sector, while energy use in mining declined slightly towards the end of the past decade. Although energy demand has shifted towards manufacturing and services, the availability of comparatively cheap energy, especially electricity, has led to its inefficient use (Winkler, 2007:26).

For this reason, the White Paper on Energy Policy (DME, 1998) established the following priorities for the electricity supply sector:

- to continue the electrification programme;
- to restructure the sector to introduce greater competition;
- to move to more cost-reflective tariffs; and
- to promote energy efficiency through an integrated planning approach (Spalding-Fecher & Matibe, 2003:722).

An energy efficiency strategy was consequently released in 2005 that stipulated a national energy efficiency target of 12% by 2015, disaggregated to include sectoral targets. However, despite the White Paper specifying the establishment of institutional capacity to enable energy efficiency targets to be met, almost no institutional development, or mandatory energy efficiency implementation, occurred (Tyler, 2010:580). This energy efficiency strategy has the potential to shift South Africa's competitive advantage from a traditional reliance on low-cost electricity (and, hence, energy-intensive products such as gold mining, aluminium smelting and other products) to one that uses electricity more efficiently. Part of such an industrial strategy would be a focus on export value added products, which have a lower energy and emission intensity (Winkler, Howells & Baumert, 2007:220).

According to Winkler *et al.* (2007:225), the benefits of industrial energy efficiency in South Africa include the following: significant reductions in local air pollutants (oxides of sulphur, oxides of nitrogen and particulates, by approximately 4-6%); improved environmental health; the creation of additional jobs; reduced electricity demand; delays in new investment in electricity generation; and, the creation of new competitive advantages through more efficient production. The co-benefit of reducing GHG emissions is substantial, at 5% of SA's total projected energy CO_2 emissions, by 2020.

Energy efficiency is therefore likely to become the future of production, as well as the solution to a sustainable approach to manufacturing that can benefit the global economy, the community and the environment.

1.2 Problem Statement

The South African government provides a number of regulations, as well as other legislation, to assist and promote energy efficiency projects' implementation in the South African manufacturing industry. This includes the South African Constitution, of which Section 24 is particularly relevant, namely that –

every person has the right (a) to an environment that is not harmful to their health and wellbeing; and (b) that everybody has a right to have the environment protected for the benefit of present and future generations, through reasonable legislative and other measures (South Africa, 1996:1251).

Note that the focus is on everybody, implying human beings. The Constitution gave impetus to the development of the National Environmental Management Act (NEMA) No. 107 of 1998, which is widely applied in dealing with environmental matters. The White Paper on Energy Policy (DME, 1998) states that significant potential exists for energy efficiency improvements in South Africa. In developing policies to achieve greater efficiency of energy use, the South African government is mindful of the need to overcome shortcomings in energy markets. The government would create energy efficiency consciousness, and encourage energy efficiency in commerce and industry, would establish energy efficiency norms and standards for commercial buildings and industrial equipment, and voluntary guidelines for the thermal performance of housing. A domestic appliance labelling programme was to be introduced, and publicity campaigns undertaken, to ensure that appliance purchasers were aware of the purpose of the labels. Targets for industrial and commercial energy efficiency improvements were to be set and monitored (DME, 1998:14).

The Integrated Energy Plan for the Republic of South Africa (DME, 2003:22) supports that increased energy efficiency reduces energy demand significantly, with a substantial decrease in cost to the energy system. Moreover, the use of coal and other forms of energy can be enhanced through the implementation of programmes for improved energy efficiency. In addition, the plan informs that energy efficiency measures are generally cost effective, with payback periods of one to three years being acceptable, depending on the circumstances (DME, 2003:23).

The DME developed an energy efficiency strategy in 2005, which set a national target for energy efficiency improvement of 12% by 2015. This target was expressed in relation to the forecast national energy demand at that time, and therefore allowed for current expectations of economic growth. Efforts were to be made to give Eskom responsibility for meeting a portion of the target set out in this strategy, through its annual shareholder compact (DME, 2005:5).

Energy efficiency improvements would be achieved largely by means of enabling instruments and interventions. These would include, among others, economic and legislative means, efficiency labels and performance standards, energy management activities and energy audits, and the promotion of efficient practices (DME, 2005:ii).

There are no records in place, which are readily available, to demonstrate the statements pertaining to the abovementioned regulations. This has posed a challenge in getting buy-in from industry decision-makers, who have the power to allow companies to take part in programmes of implementing energy efficiency.

1.3 Research Aim and Objectives

1.3.1 Research aim

This research aims to investigate the benefits of implementing energy efficiency projects within the automotive component manufacturing companies, which reduce both energy use and environmental pollution, and are of economic benefit to manufacturing companies.

1.3.2 Research objectives

The objectives of the study are as follows:

- To identify energy efficiency projects implemented by three selected automotive component manufacturing companies;
- To determine the benefits gained by three automotive component manufacturing companies through implementing energy efficiency projects; and

- To investigate the perception of company management and operational staff towards implementing energy efficiency projects.

1.3.3 Hypotheses

There are three hypotheses for this research:

1. HO- Implementing energy efficiency projects has no effect on the automotive component manufacturing industry.
2. H1- Implementing energy efficiency projects has benefits for the automotive component manufacturing industry.
3. H2- Implementing energy efficiency projects has no benefits for the automotive component manufacturing industry.

1.4 Delineation, Limitations and Assumptions

1.4.1 Delineations

The research will only be focusing on three component manufacturing companies, based in the Nelson Mandela Bay Municipality.

1.4.2 Limitations

The limitation factors of the study will be influenced by confidentiality policies within the companies; therefore, information provided for the research will be according to what is, and can be, shared by the companies. Limitations of access to company sites and company data may have an impact on research results. In addition, annual automotive industrial action may result in the researcher’s safety being compromised, and may cause serious project delays, as during such periods production activities are stopped.

Also, due to urgency production factors, management may prevent the researcher's entrance to the companies' sites.

1.4.3 Assumptions

For this research study, the following is assumed:

- That management will not interfere with the responses of participating staff members;
- That participants will be factual when completing the questionnaire; and
- That the participants will not influence one another, in their working environment, to ensure that questionnaires are answered to the satisfaction of other participants.

1.5 Chapter Overviews

The dissertation will consist of five chapters. The chapter titles will be as follows: Introduction, Literature Review, Methodology, Research Results, and, lastly, Conclusion and Recommendations.

Chapter 1 – Introduction: Background information was provided regarding the research topic of 'energy efficiency'. The chapter also provided clear definitions that apply to the research. Additionally, the research problem and research statement were explained.

Chapter 2 – Literature Review: The focus will be on works previously published by other scholars (Hofstee, 2006:91). Material relevant to the topic at hand will therefore be identified and reviewed. The works will then be collated as part of the literature review.

Chapter 3 – Methodology: Reasons for selecting study areas will be explained. The research will be conducted in a mixed mode method; therefore, both qualitative and quantitative methods will be applied. A questionnaire for management and staff will be compiled and distributed, to gain understanding of people's perceptions on implementing energy efficiency projects. Municipality utility bills and production data will be collected and analysed. Limitations of the research will also be established, to ensure that provision is made for problems identified.

Chapter 4 – Research results: The collected data will be divided into two sections, and analysed separately; qualitative and quantitative data findings will therefore be described individually. Chapter 4 will have subsections, to ensure that the findings are easily understood.

Chapter 5 – Conclusion and recommendations: Accomplishment, or lack of realisation, of the research objectives, will be illustrated. A summary of the findings will then be given and final conclusions drawn. This information may include research conclusions, recommendations, and possible further energy efficiency projects.

Chapter 2

Literature Review

2.1 Introduction

This chapter focusses on existing literature on energy efficiency, and the investigation of influencing factors originating energy efficiency as a solution to environmental challenges such as climate change. The chapter also reviews the development of South African policies and legislation on energy efficiency. The chapter concludes with a citation analysis to determine the gap in energy efficiency.

2.2 Energy Efficiency

'Energy efficiency' is a term widely used, often with different meanings in public policy-making. A clear distinction between energy efficiency and energy conservation is that the former refers to adoption of a specific technology that reduces overall energy consumption without changing the relevant behaviour, while the latter implies merely a change in consumer behaviour (Oikonomou, Becchis, Steg & Russolillo, 2009:4787).

According to the most recent estimates of the International Energy Agency, in 2008 the manufacturing industry accounted for about 79% of global coal consumption, and more than one-third of global gas consumption, and also used 41.7% of all electricity produced. Moreover, recent research has shown that the industrial sector uses "*more energy globally than any other end-use sector*" (Trianni & Cagno, 2012:494).

Limited energy sources, and the challenges of converting energy in efficient cycles, require a continuous effort to utilise energy as sensibly as technologically possible (Weinert, Chiotellis & Seliger, 2011:41). Many countries have attached considerable importance to energy efficiency, due to the scarcity of energy sources, the environmental effects of fossil fuel consumption, and the idea of maintaining sustainable development (Özkara & Atak, 2015:495).

With this intention as a prerequisite for successful approaches to foster energy efficiency, deeper insight into energy consumption behaviour is necessary. From a production perspective, a deeper energy analysis of the production equipment (actual machines, for example) is important (Herrmann & Thiede, 2009:223). It is important to define the boundaries of the efficiency improvement, in measuring the rebound effect (Turner, 2009:649).

It is hoped that with physical energy prices constant, a decrease in the price of energy in efficiency units will generate an increase in the demand for energy in efficiency units. This is the source of the rebound effect, and the key determinant of the change in energy use and CO_2 emissions levels, in response to the increase in technological progress (Turner & Hanley, 2011:713).

Governments use two general policy approaches, as well as various streams of influence, to encourage industry to improve its energy efficiency. The general approaches are company- or sector-specific measures, and industry- or economy-wide measures, focused on the environmental and social circumstances within which the companies and sectors operate. The measures include regulations, directed financial instruments and agreements, energy taxes, carbon taxes and emission trading (Tanaka, 2011:6533).

Geller, Harrington, Rosenfeld, Tanishima and Unander (2006:556) state that the major OECD countries – Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the United Kingdom (UK) and the United States (U.S.) – have significantly reduced the need for energy to fuel economic growth over the past three decades. Total primary energy supply (TPES) per unit of GDP has fallen sharply. The decline in primary energy per unit of GDP has been driven by improved energy efficiency in key end-users, as well as changes in the structure of human and economic activities. Changes in the mix and efficiency of energy supply have also affected this ratio.

New Zealand's energy policy is fundamentally driven by ecological concerns, through their energy efficiency agency (Energy Efficiency and Conservation Authority, 2015). The Australian approach to energy efficiency is basically a beneficial side effect to their approach to the problem of GHG effect induced climate challenges (Saidel & Alves, 2003:131). China was able to limit energy demand growth to less than half of its GDP growth. This was achieved through very aggressive energy-efficiency programmes organised by the central government, working closely with provincial and municipal authorities. The main features of the governmental policy and implementation approaches during this period included tight oversight of industrial energy use, including monitoring requirements for large industrial energy users, in support of energy quotas, as well as the closing of inefficient facilities and the promotion of efficient technologies (Zhou, Levine & Price, 2009:6439).

In Japan, a government-affiliated financial institution provides low-interest loans for funding the introduction of energy conservation systems. In the UK, the Carbon Trust runs an interest-free loan scheme for energy efficiency investment of SMEs (Tanaka, 2011:6532). The German energy audit programme, ‘‘Sonderfonds Energieeffizienz fur KMU’’, was established in 2008, and provides grants for on-site energy audits in SMEs (Fleiter, Schleich & Ravivanpong, 2012:863). The energy costs in Germany are high, according to international comparison. For instance, at an inner-European comparison, the electricity prices for German industry are already around 14% higher than for other European countries (Javied, Rackow & Franke, 2015:156). A variety of opportunities exist within U.S. vehicle assembly plants, to reduce energy consumption while maintaining or enhancing the productivity of the plant (Galitsky, 2008:9).

2.3 Influencing Factors of Energy Efficiency

In 1972, Stockholm, Sweden, hosted the first United Nations Conference on the Human Environment, which was attended by 113 delegates and two heads of state – Olaf Palme (Sweden) and Indira Gandhi (India).

From 3-14 June 1992, Rio de Janeiro hosted the United Nations Conference on Environment and Development (UNCED). The focus of this conference was the state of the global environment, and the relationship between economics, science and the environment, in a political context. The conference concluded with the Earth Summit, at which leaders of 105 nations gathered to demonstrate their commitment to sustainable development (Meakin, 1992).

For this reason, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted and signed by 162 countries in 1992 at the Rio Earth Summit (United Nations, 2016). The UNFCCC became a blueprint for precautionary action against the threat of global climate change. The Convention highlighted the fact that human activities, such as the burning of fossil fuels, are releasing large quantities of gases into the Earth's atmosphere (Sustainable Environment, 2016).

As a result, by 1995, countries realised that emission reduction provisions in the Convention were inadequate. They launched negotiations to strengthen the global response to climate change, and, two years later, adopted the Kyoto Protocol (UNFCCC, 2016). This Protocol is an international agreement, linked to the UNFCCC, which commits its parties by setting internationally binding emission reduction targets. The Protocol was adopted in Kyoto, Japan, on 11 December 1997, and entered into force on 16 February 2005 (UNFCCC, 2016). Under the Protocol, industrialised nations pledged to cut their yearly emissions of carbon, as measured in six GHG, by varying amounts, averaging 5.2% by 2012, as compared to 1990 (Henson, 2011).

Since the initial commitment period to the Protocol ended in 2012, the primary focus of Conference of the Parties (COP) 17 was to negotiate and ratify a new global climate change framework that could deliver the emission reductions needed to meet the targets set out in the Convention (PricewaterhouseCoopers, 2011). This 17th Conference of the Parties (COP 17) of the United Nations Framework Convention on Climate Change (UNFCCC), and the 7th session of the Conference of the Parties serving as the meeting of the Parties (CMP 7) to the Kyoto Protocol (COP17, 2016).

Consequently, COP 17, held in Durban from 28 November to 9 December, 2011, known as the United Nations Climate Change Conference, was set to bring together representatives from the world's governments, international organisations and civil society. The discussions sought to advance the implementation of the Convention and the Kyoto Protocol. One of the central outcomes of the meeting in South Africa was to pave the way for a legally binding agreement under the UN Climate Convention, applicable to all parties, to be completed by 2015, and to come into effect from 2020 (BuaNews, 2012). Meanwhile, the Protocol would continue into a second commitment period, thus retaining the important political value of rules-based emission reductions from a group of industrialised countries, while preserving important mechanisms such as emissions trading (Morgan & Cameron, 2011).

The increasing emphasis on climate change and sustainable development objectives, in recent years, especially since the Rio Summit 2 in 1992, COP 3 in 1997, and international initiatives such as the G8 Gleneagles Summit in 2006, has also influenced the recent increasing focus on energy efficiency conservation and climate change (Tanaka, 2011:6533). Industry's large energy use and vast potential for energy savings therefore make it an attractive target for improving energy security and climate mitigation through increased energy efficiency (Tanaka, 2011:6532).

2.4 Energy Efficiency in the Natural Environment

Improvements in energy efficiency have been suggested both as a measure of progress towards sustainable development, and as a means of achieving sustainability (Hanley, McGregor, Swales & Turner, 2009:692). Increasing energy efficiency is critical towards mitigating GHG emissions from fossil-fuel combustion, reducing oil dependence, and achieving a sustainable global energy system (Greene, 2011:608).

An equally important relevant question is thus the extent to which improvements in energy efficiency translate to improvements in both the level of absolute emissions and the ratio of gross domestic product (GDP) to carbon dioxide (CO_2) emissions at the level of the economy as a whole (Turner & Hanley, 2011:709). In addition to energy savings, this programme reduces emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NOx) (Galitsky, 2008:14).

Again, the improvement in energy efficiency has been accepted as one of the most cost-effective approaches towards sustainable economic development and the reduction of continuously increasing energy consumption. Also, the environmental benefits are important. Reduction of GHG emissions, and CO_2, SO_2 and smoke emissions, are key objectives, at a local level, for many communities living adjacent to heavily industrialised areas (Inglesi-Lotz & Pouris, 2012:113). Rosen, Dincer and Kanoglu (2008:128) agree that increasing efficiency is often an important way to reduce costs, resource use and environmental emissions.

In contrast, an opposing statement by Herring (2006:10) states that energy efficiency is not as environmentally friendly as many claim. Its promotion will not necessarily lead to a reduction in energy use and, hence, reduced CO_2 emissions. It will, however, save consumers money, promote a more efficient and prosperous economy, and allow the financing of the move towards a fossil-free energy future. It is a means, not an end.

2.5 Energy Management

A successful programme in energy management begins with a strong organisational commitment to continuous improvement of energy efficiency (Galitsky, 2008:12). Energy management is of great and ever-increasing importance, both for companies and for society as a whole. Its core objectives are supply security, economic efficiency and environmental protection. For individual companies, there exist different reasons to apply energy management practices, implement related measures, and establish an energy management system (Javied *et al.*, 2015:160).

In addition, Galitsky (2008:12) explains that changing how energy is managed, by implementing an organisation-wide energy management programme, is one of the most successful and cost-effective ways to bring about energy efficiency improvements. Again, the potential for energy savings in manufacturing lies not only in continuously increasing the energy efficiency of production processes, logistics, buildings and product life cycles, but also in developing novel energy monitoring and management approaches (Weinert *et al.*, 2011:41).

"According to May, Barletta, Stahl and Taisch (2015:47) energy-related information allows the assessment of optimisation and improvement potential of energy efficiency measures, hence it becomes important to provide knowledge that highlights the overall state of the factory and its performance regarding energy consumption. In this regard, performance indicators serve as a measure to decide whether a system is working as it is designed for, and helps define progress toward a pre-set target. This enables better monitoring and control of energy consumption, which is of the utmost importance for current and future enterprises, to improve energy efficiency in production".

Energy savings in production sectors are likely to have stronger indirect and economy-wide impacts than energy savings in consumption activities. Energy substitution might possibly be substantially greater in production than in consumption (Allan, Hanley, McGregor, Swales & Turner, 2007:780). Henceforth, to foster industrial application, a systematic approach is needed to ensure full coverage of all energy-related aspects, and enable the derivation and prioritisation of strategies (Herrmann & Thiede, 2009:225).

2.6 South African Energy Efficiency Legislation and Incentives

Table 2.1, below, provides a list of legislation, and the description thereof, compiled for energy efficiency in South Africa.

Table 2.1: Summary of South African energy efficiency legislation.

White Paper on Energy Policy (1998)	This paper identifies the need for demand side management and the development and promotion of energy efficiency in South Africa. It requires energy policies to consider 'energy efficiency and energy conservation' within the integrated resource planning (IRP) framework from both supply and demand side, in meeting energy service needs.
National Energy Efficiency Strategy of the Republic of South Africa (NEES) (2005, reviewed 2008)	NEES set out a national target for energy efficiency of at least 12% by 2015, with sectoral targets ranging from 9% for transport, through to 15% for industry, commerce and the public sector.
Electricity Regulation Act No. 4 of 2006	The Act established a national regulatory framework for the electricity supply industry, which made the National Energy Regulator (NERSA) the custodian and enforcer of the National Electricity Regulatory Framework and Initiatives.
National Energy Act No. 34 of 2008	The National Energy Act was legislated to ensure that diverse energy resources are available, in sustainable quantities and at affordable prices, to the South African economy, in support of economic growth and poverty alleviation, taking into account environmental management requirements and interaction among economic sectors. This Act makes provision for the development of the Integrated Energy Plan and the formation of the South African National Energy Development Institute (SANEDI), whose functions are to undertake energy efficiency measures, as directed by the Minister, to increase energy efficiency throughout the economy, to increase the gross domestic product per unit of energy consumed, and to optimise the utilisation of finite energy resources.
Integrated Resource Plan (IRP) 2010	The IRP 2010's revised balanced scenario sets out specific targets for renewable energy and energy

	efficiency. The IRP provides insight into the proposed new build options, including renewables, as well as the energy savings expected from Demand Side Management Programmes.
Industrial Policy Action Plan (IPAP2) 2012/2013 – 2013/14	IPAP2 aims to better align trade and industry policies for certain industries, of which five new main groups of focus will be targeted. Among the new groups are the green and energy-saving industries.
Industrial Policy Action Plan (IPAP) 2014/2015, released by the DTI for public comment (2012)	IPAP 2014/2015 includes the Manufacturing Competitiveness Enhancement Programme (MCEP) that will provide enhanced manufacturing support. The Production Incentive (PI) programme will include a Green Technology Upgrading Grant of between 30-50% for investments in technology and processes that improve energy efficiency and greener production processes.
Income Tax Act – Regulations on tax allowances for Energy Efficiency Savings	Section 12I allows for additional depreciation allowances up to 55% for Greenfield projects over R200 million, one of the rating criteria being energy efficiency savings. Section12L provides a tax deduction to a taxpayer who is energy efficient with a focus on renewable energy. Other tax allowances that are applicable to business include Section12C, Section11e, Section13 and others that provide general depreciation of asset allowances that are applicable not only to ESCo businesses, but also to any business that meets the section requirements.
Building Regulations & Building Code (SANS 10400-XA:2011) with SANS 204	The regulations require construction standards on energy efficiency and energy use in the built environment, with all new buildings requiring energy efficiency initiatives prior to municipal approval.
SANS 941: Energy efficiency of electrical and	This standard covers energy efficiency requirements, measurement methods, and energy efficiency labelling of

electronic apparatus	electrical and electronic apparatus, thus impacting manufacturers and importers.
Carbon Taxes – 2013/2014	It was envisaged that a carbon tax, proposed by the National Treasury, would be implemented in 2013/2014 at a rate of R120 per ton of carbon dioxide equivalent (CO_2e)on direct emissions and would increase by 10% p.a. until 2020.
Gazetted energy tax incentive regulations	The National Treasury and the Department of Energy have gazetted energy efficiency tax incentive regulations that will incentivise investment in energy efficiency measures; these would be finalised at the end of 2012.

Source: SANEDI, 2016a.

Figure 2.1, below, illustrates South Africa's hierarchy for energy efficiency policies.

SOUTH AFRICAN ENERGY EFFICIENCY HIGH LEVEL POLICY MAP

Acronyms – DoE

1: BUSA – Business Unity South Africa
2: CDM – Carbon Development Mechanism
3: DOE – Department of Energy
4: DNA – Designated National Authority
5: DSM – Demand Side Management
6: ECS – Energy Conservation Scheme
7: EE – Energy Efficiency
8: EELN – EE Leadership Network
9: EETMS – Energy Efficiency Target Monitoring System 7:
10: ESCo – Energy Services Company
11: IEP – Integrated Energy Plan
12: IRP – Integrated Resource Plan
13: IDM – Integrated Demand Management
14: MYPD – Multi-Year Price Determination
15: NEEA – National EE Accord
16: NEEAP – National EE Action Plan
17: NERSA – National Energy Regulator of SA
18: R&C – Residential & Commercial Consumers
19: Stds – Standards
20: SO – Standard Offer
21: SP – Standard Product
22: SWH – Solar Water Heating
23: PCP – Power Conservation Programme

SUPREME LAW

Constitution

(DoE) | Other Government

POLICY AND STRATEGY

Energy – DoE

1: White Paper: Energy Policy (1998)
2: White Paper: Renewable Energy (2003)
3: EE Strategy 2005 (review 2008)
4: EE Strategy 2nd Review (2011)
5: Draft IEP (2013)
6: 1st NEEAP (2013)

Industrial – DTI and EDD

1: IPAP (2012)
2: NGF: Framework (2011)
3: Green Economy Accord

Environment & Climate Change - DEA

1: White Paper: CC Response Policy

Transport - DoT

1: National Land Transport Act (2009)
2: National Transport Master Plan (2007)

Relevant Policy and Strategy – Other

1: NDP (Presidency) 2012
2: Corporate Policies, Legislation, Regulations & non Mandatory Frameworks (Private Sector)

ENERGY REGULATION AND LEGISLATION

1: Electricity Regulation Act (2006)
2: Electricity Regulation Act – Stds for Reticulation (2008)
3: National Energy Act (2008)
4: National Energy Act – Allowances for EE Savings (2011)
5: Electricity Regulations IRP (2011)
6: Revision of Regulatory Rules for EE & DSM (2010)
7: Advanced Metering Infrastructure - R&C Consumers (2008)

Note: The preferred approach towards achieving policy objectives is through standards and not regulation. Standards are good principles, practices, or guidelines which can be either of a mandatory or voluntary nature. When incorporated by reference into regulations, standards become binding on applicable parties.

1: SANS 10400XA DTI (Promulgated Nov 2011)
2: SANS 50001 and 50010

ENERGY EFFICIENCY INCENTIVES, TAXES AND REBATES

All Mandatory Programmes are Mandated by National Treasury and then Implemented by the Appointed Ministries

1: Environmental Levy on Non-Renewable Electricity - Eskom (2009)
2: Section 12L of the Income Tax Act, Act No.58 of 1962
3: MYPD Funding for DSM Programme – Eskom (2011-2013)
4: Regulations on mandatory provision of energy data (addition to Energy Act)

Industrial - DTI

1: Section 12I of the Income Tax Act, Act No.58 of 1962

South African Revenue Services

1: Carbon Dioxide Vehicle Emissions Levy (2011)
2: Carbon Tax Discussion Paper, National Treasury, (2010)
3: Carbon Emissions Tax in the National Budget Review (2012)
4: NT announced Carbon Tax to be introduced January 1, 2016

Acronyms – Other Government

1: CC – Climate Change
2: DEA – Dept of Environmental Affairs
3: DPW – Dept of Public Works
4: DTI – Dept of Trade and Industry
5: EDD – Economic Development Department
6: IPAP – Industrial Policy Action Plan
7: NCPC – National Cleaner Production Centre
8: NDP – National Development Plan
9: NGP – New Growth Path
10: NT – National Treasury
11: SANAS – SA National Accreditation Service
12: V-NAMA – Vertically integrated nationally appropriate mitigation action

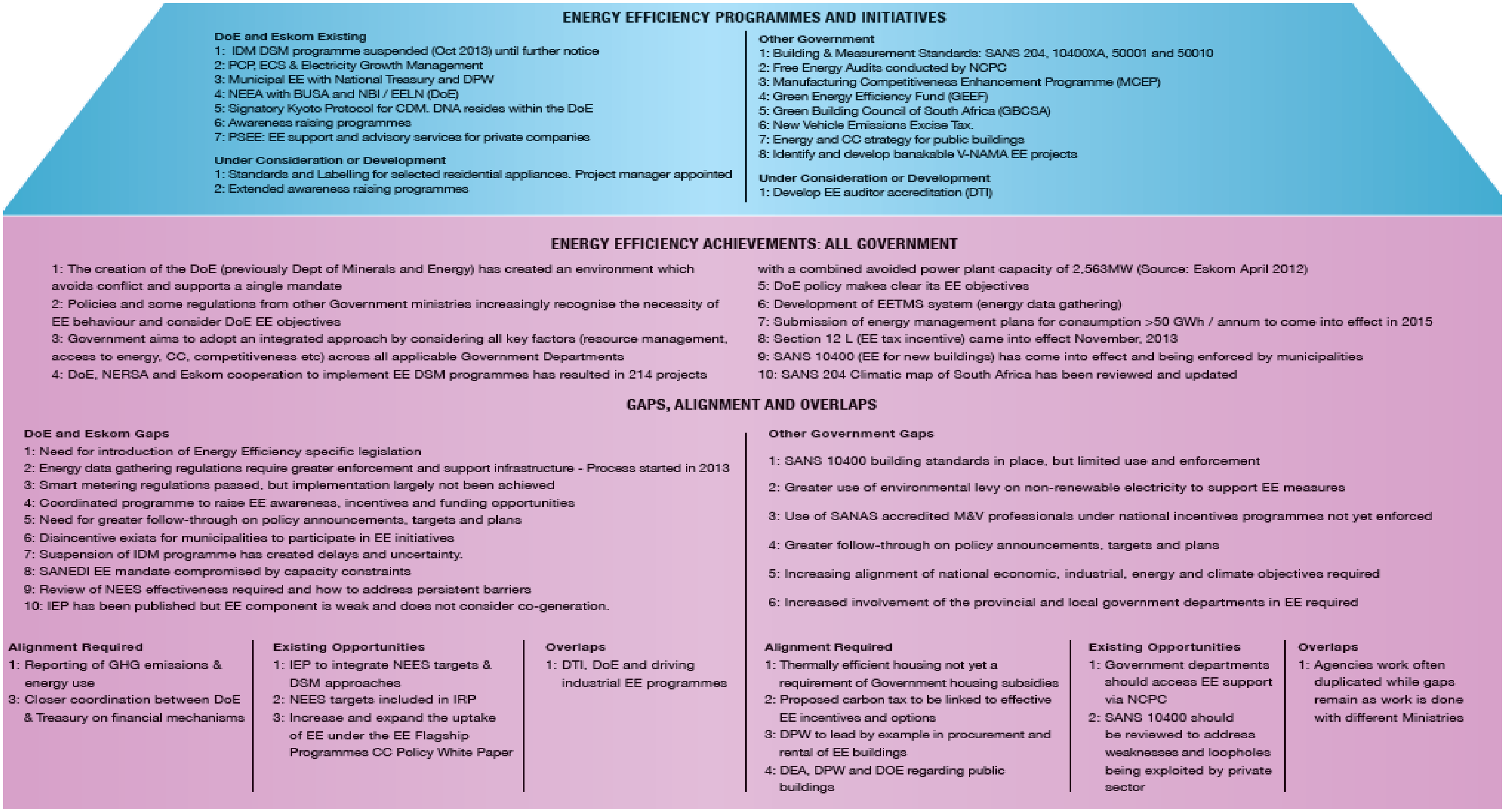

Figure 2. 1: South African energy efficiency high-level policy map**.**

Source: SANEDI, 2016a.

2.7 Energy Efficiency Programmes and Initiatives in South Africa

The government of South Africa has put programmes in place to promote and support energy efficiency efforts in the manufacturing industry. These programmes are described below.

The National Cleaner Production Centre of South Africa (NCPC-SA) is a national government programme that promotes the implementation of resource efficiency and cleaner production (RECP) methodologies to assist industry to lower costs through both reduced energy, water and materials usage, and waste management. Due to the energy crisis and ever-rising costs of energy, both locally and globally, the NCPC-SA currently has a strong focus on supporting South African industry in managing its energy consumption. In partnership with United Nations Industrial Development Organization (UNIDO), the NCPC-SA implements the Industrial Energy Efficiency Improvement Project in South Africa (IEE Project). This project was designed to help transform industries' energy use patterns, and helping them adopt a more systematic and holistic approach to energy management within their organisations and plants (National Cleaner Production Centre, 2016).

The Manufacturing Competitiveness Enhancement Programme (MCEP) offers a new suite of incentives for existing manufacturers, that is designed not only to promote competitiveness in the manufacturing arena, but also to ensure job retention in this sector (Industrial Development Corporation, 2014). It includes a package of incentives specifically designed for established manufacturers, with the aim of promoting competitiveness and retaining jobs (SAnews.gov., 2014).

The objective of the Green Technology and Resource Efficiency Improvement incentive is to support both projects with green technology upgrades, and business development activities that will lead to cleaner production and resource efficiency, as well as engineering and conformity assessment services that support the green economy through the manufacturing sector. The applicant(s) must submit, together with their application, a cleaner production and/or resource efficiency audit or green technology assessment report for the project. The cleaner production and/or resource efficiency audit and/or green technology assessment recommendations report should not be older than 24 months at the time of submitting an application. Applicants are encouraged to use the National Cleaner Production Centre (NCPC) for this purpose (Department of Trade and Industry, 2014).

The Green Energy Efficiency Fund (GEEF) supports the introduction of energy efficiency and self-use renewable energy technologies, and will ultimately continue contributing to global climate protection, while supporting South Africa's economic development and growth (Industrial Development Corporation, 2016a).

Energy efficiency and renewable energy initiatives are vital in maintaining the energy supply-and-demand balance, and in ensuring energy security within South Africa. Energy efficiency needs to be a strategic priority for companies as South Africa moves to higher, cost-reflective electricity pricing.

The Green Energy Efficiency Fund is set to achieve the following three objectives:

- Improved energy efficiency through reduced energy consumption, facilitating South Africa’s transition towards a low-carbon economy;
- Long-term enterprise competitiveness and job creation through energy-saving support of self-use renewable energy technologies in South Africa; and
- Continued contribution to global climate protection, while supporting South Africa’s economic development and growth (Industrial Development Corporation, 2016b).

2.8 Search Topic Citation Matrix

A citation analysis was conducted, using the search string and keywords 'energy efficiency', 'green economy' and 'environmental management' on the citation resources Web of Science, Scopus and Google Scholar. This was also done to identify any possible trends in research possibilities. The keywords identified included the following:

- Automotive industry AND energy efficiency
- Benefits of energy efficiency
- Energy efficiency
- Environmental management AND automotive industry
- Environmental management AND energy efficiency
- Green economy AND energy management
- Green industries AND energy efficiency
- Green economy AND energy efficiency
- Green economy approach AND efficiency
- Industrial energy management
- Manufacturing AND energy efficiency
- Processes of energy efficiency

Results from the search strings are illustrated in the table below. It was unexpected to find that some keywords had no records in the citation resources, specifically the keywords 'green economy'.

Table 2.2: Summary of citation analysis.

No	Keyword combinations	Citation Resources		
		Web of Science	**Scopus**	**Google Scholar**
1	**"automotive industry" AND "energy efficiency"**	26	172	8,190
2	**“benefits of energy efficiency"**	24	43	2410
3	**“energy efficiency”**	63 746	86 318	1 230 000
4	**“environmental management” AND “automotive industry”**	26	100	5160
5	**"environmental management" AND "energy efficiency"**	61	457	28,500
6	**"green economy" AND "energy management"**	0	3	1,160
7	**"green industries” AND “energy efficiency"**	1	9	1,190
8	**"green economy” AND "energy efficiency"**	0	1	78
9	**"green economy approach” AND "efficiency"**	0	0	1
10	**"industrial energy management"**	22	81	802
11	**"manufacturing" AND "energy efficiency"**	1,840	1,886	102,000
12	**"processes of energy efficiency"**	0	6	13

Source: Own.

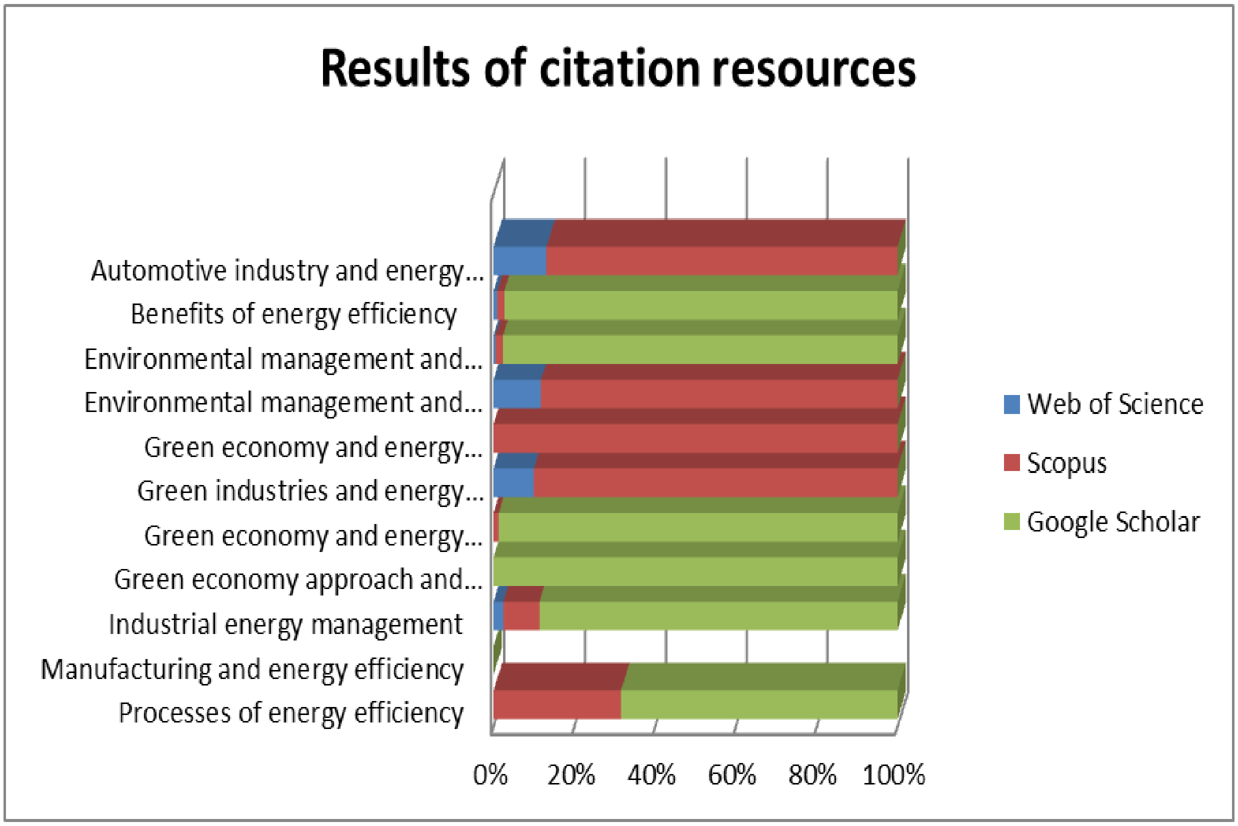

Figure 2.2: Citation analysis table.

Source: Own.

The citation analysis of the topic “the effect of energy efficiency on the environment and green economy” indicated a gap in research. This gap, and existing scholarly, peer-reviewed literature, served as sufficient motivation to conduct this research study.

The following figure gives an indication of the coverage and type of items in each citation resource. When comparing the data below with the outcome of the research citations, the results are remarkably in line with the diversity in citation metrics:

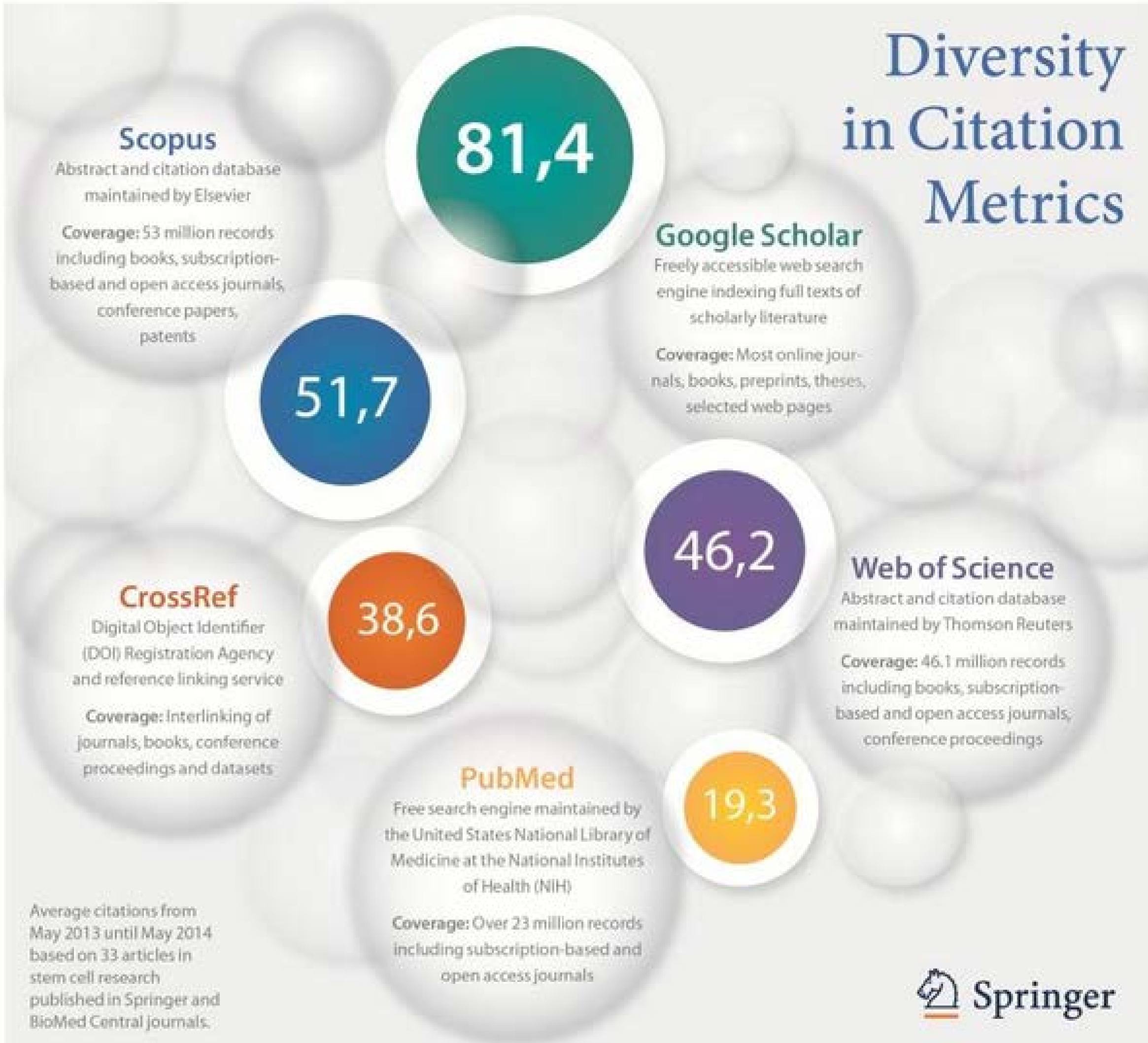

Figure 2.3: Diversity in citation metrics.

Source: O'Neill, 2014:1.

The above indicates Web of Science exclusivity – 46.1 million records, including books, journal articles and conference proceedings. Scopus coverage totalled 53 million records, including books, journal articles, conference proceedings and patents. Scopus coverage includes all scholarly information, indexed on the Web, which can be searched by a search engine: books, journal articles, conference proceedings, patents, preprints, theses and dissertations, certain websites and digital archives. The search results from Web of Science were usually less than those of Scopus and Google Scholar, and Scopus had more than Web of Science, but less than Google Scholar. Google Scholar retrieved the most search results.

The citation analysis for the study demonstrates the same findings as the results of the diversity in citation metrics. The conclusion demonstrated below is from the results of the citation analysis of keywords that included 'energy efficiency'. Google Scholar contributed most of the results, while Web of Science had the least.

The following pie chart demonstrates the outcome of the citation research results from the different sources:

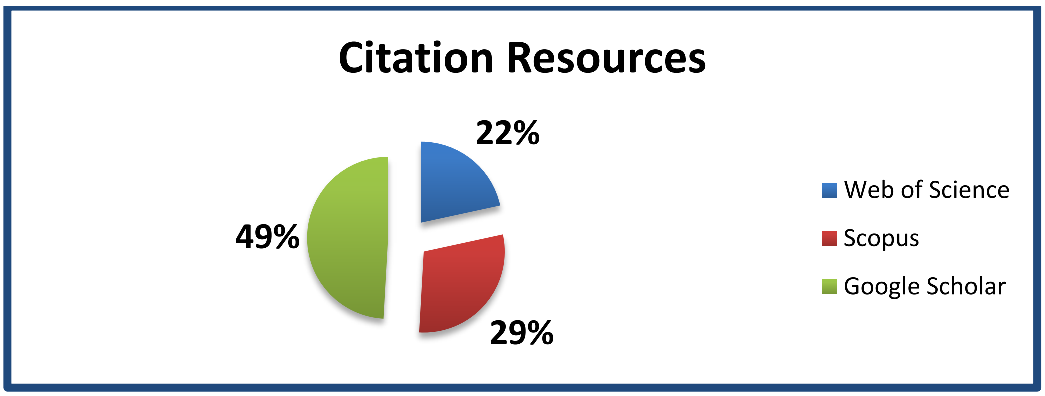

Figure 2.4: Citation resource results.

Source: Own.

2.9 Conclusion

Turner and Hanley (2011:719) suggest that the improvements in energy efficiency produce a range of general equilibrium effects: a pure efficiency change – which reduces emissions and energy use, and substitution, competitiveness and structural change effects – which tend to increase energy use and a "rebound" in emissions.

On the other hand, the results presented by Hanley *et al.* (2009:706) imply that in order to ensure that increased energy efficiency generates improvements in local sustainability indicators, it is necessary to counteract the positive competitiveness effects that occur due to the fall in the cost of production in energy-intensive sectors. In addition, Hanley *et al.* (2009:705) find that an improvement in energy efficiency results in an initial fall in energy consumption, but this is eventually reversed. Galitsky (2008:12) agrees with Hanley *et al.* (2009:705-706), stating that energy efficiency improvements might not reach their full potential, due to the lack of a systems perspective and/or proper maintenance and follow-up.

This chapter comprised literature reviewed from other scholars. The focus was on energy efficiency, energy management and the natural environment. Citation analysis was conducted, to determine the gap within the energy efficiency scope.

The following chapter, Chapter 3, presents the study area and research methodology for the research study. The chapter encompasses the research design, research method and data analysis. Ethics is also considered as an important part of the chapter, and includes confidentiality, anonymity, limitations and assumptions.

Chapter 3

Study Area and Methodology

3.1 Introduction

This chapter addresses the research methodology used to carry out this research, the study area in which research was conducted, and the reasons for selecting the study area. The instruments used to collect the data are also discussed. Ethical considerations are dealt with, study limitations and data sampling are comprehensively explained, and a description of the data analysis method is provided.

3.2 Research Design

The research approach took the form of a case study, using a mixed mode research method for the study. Tashakkori and Creswell (2007b:3) broadly define mixed methods research as "*research in which the investigator collects and analyses data, integrates the findings, and draws inferences, using both qualitative and quantitative approaches*". Mixed methods research, where quantitative and qualitative methods are combined, is increasingly recognised as valuable, because it can potentially capitalise on the respective strengths of quantitative and qualitative approaches. Mixed methods research questions and objectives clearly demand the use and integration of both qualitative and quantitative approaches and methods (Tashakkori & Creswell, 2007a:207).

Quantitative research (that is, a positivist paradigm) has historically been the cornerstone of social science research. Purists call for researchers to "*eliminate their biases, remain emotionally detached and uninvolved with the objects of study and test or empirically justify their stated hypotheses*" (Johnson & Onwuegbuzie, 2004:14).

Qualitative purists support a constructivist or interpretivist paradigm, and contend that –

> multiple-constructed realities abound, that time-and context-free generalizations are neither desirable nor possible, that research is value-bound, that it is impossible to differentiate fully causes and effects, that logic flows from specific to general and that knower and known cannot be separated because the subjective knower is the only source of reality (Johnson & Onwuegbuzie, 2004:14).

To answer the research problem, both qualitative and quantitative data were collected. The qualitative method was applied, using questionnaires involving a sample of company employees. For the quantitative method, both municipality electricity bills and company production data were collected.

Figure 3.1 illustrates the research methodology approach for the study:

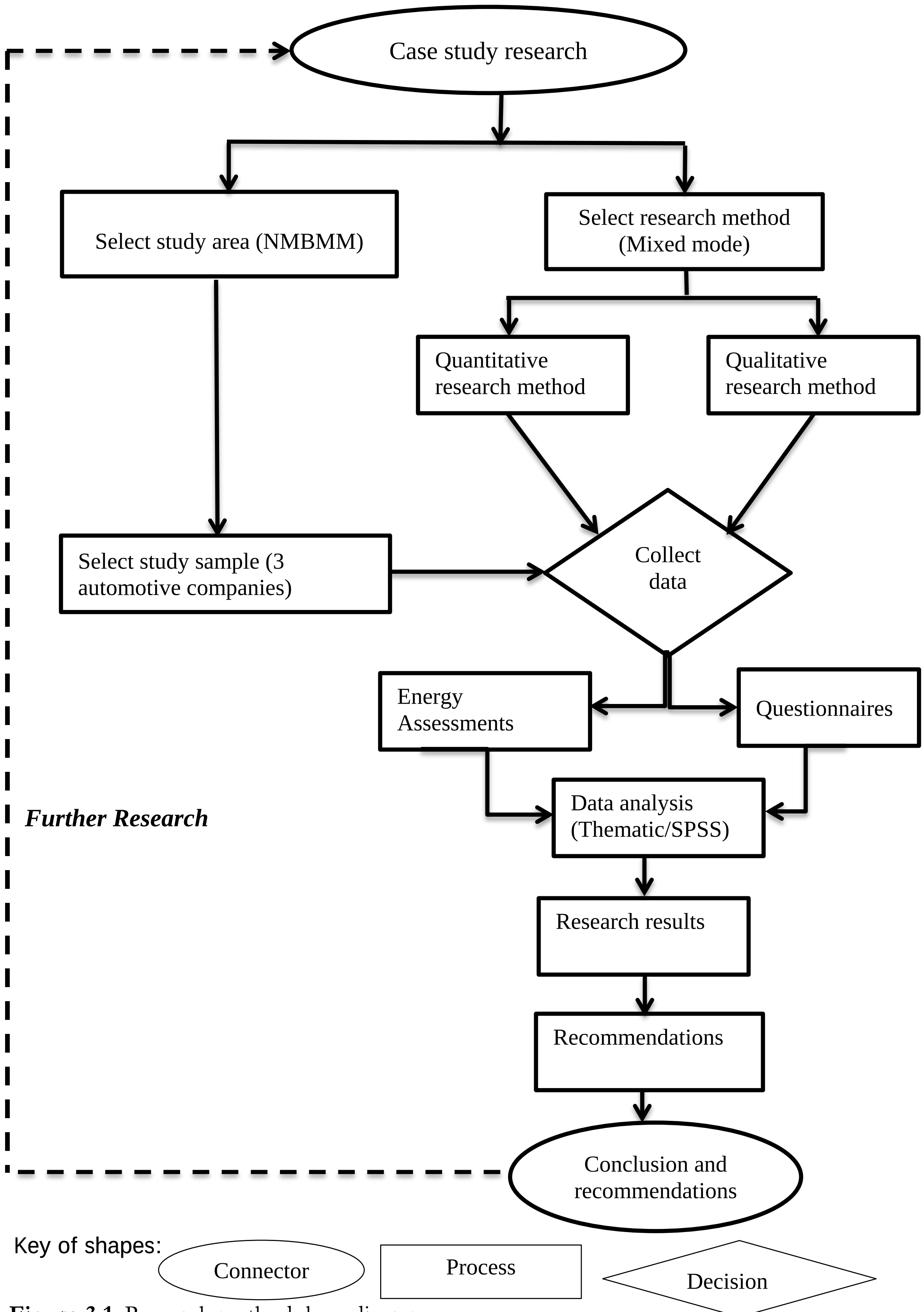

Figure 3.1: Research methodology diagram.

Source: Own.

3.3 Study Area

For this study, three automotive component manufacturing companies were selected, out of the ten automotive component manufacturing companies approached to be part of the research study. The participants were selected according to their willingness take part in the research study and the participants' comparability in terms of energy consuming processes and technologies. In addition, an important consideration was the availability of the companies to contribute and provide relevant data for the research. Due to economic pressures and production needs, only three of the automotive component manufacturing companies of the ten approached were willing to take part in energy efficiency projects. The other companies approached preferred to focus on production. In addition, companies could not afford to allocate time and resources to projects that might not yield significant results.

The participating companies were located in Nelson Mandela Bay Metropolitan Municipality, which is made up of Port Elizabeth and Uitenhage. The distance between locations is approximately 30 km. Nelson Mandela Bay is a major seaport and automotive manufacturing centre, located on the south-eastern coast of Africa in the Eastern Cape Province of South Africa. The city is one of seven metropolitan areas in South Africa. Nelson Mandela Bay Metropolitan Municipality is the hub of the automotive industry on the African continent, with many of the major vehicle and component manufacturers based in the area. It is also a major exporter of everything from manganese ore, wood, fresh produce, fruit juices, wool, skins, and automotive components (Nelson Mandela Bay Municipality, 2014). Figure 3.2 demonstrates a map of the study area indicating the boundary in which the participating companies are located.

Figure 3.2: The study area.

Source: Google Maps, 2014.

3.4 Research Method

The case study approach was used, as it provided a baseline for the study. The tasks include designing a case study, collecting the study data, analysing the data, and presenting and reporting the results. The in-depth focus on the case, as well as the desire to cover a broader range of contextual and other complex conditions, produces a wide range of topics to be covered by any given case study. In this sense, case study research goes beyond the study of isolated variables. As a by-product, and as a final feature in appreciating case study research, the relevant case study data is likely to come from multiple, not singular, sources of evidence (Yin, 2013:5).

For this research, three automotive component manufacturers were selected as the sample for the case study. Shavelson and Towne (2002:102) suggest that at least three situations create relevant opportunities for applying a 'case study' as a research method. Most importantly, the choices among different research methods, including the case study method, can be determined by the kind of research question that a study is trying to address.

3.4.1 Data collection

This research was conducted using the mixed mode. Both qualitative and quantitative methods were applied to collect data, and the qualitative and quantitative data were collected separately. As described by Creswell and Garrett (2008:3), mixed methods research resides in the middle of this continuum, because it incorporates elements of both qualitative and quantitative approaches. It is useful to consider the full range of possibilities of data collection, and to organise these methods – for example, by their degree of predetermined nature, their use of closed-ended versus open-ended questioning, and their focus on numeric versus non-numeric data analysis (Creswell & Garrett, 2008:3).

3.4.2 Quantitative data collection

The data was collected using energy assessments. These assessments were conducted by engineering consultants with extensive knowledge of energy management, energy efficiency processes and manufacturing process equipment. Sourcing of quantitative data was done by collecting electricity bills, together with production data provided. To ensure that efficiency could be measured, electricity bills for twelve months were collected, as well as production data for the same twelve-month period as the electricity bills.

The companies' manufacturing processes were studied, in order to understand the type of equipment and activities required for production. The items of equipment were known to be significant energy users, and were, subsequently, the biggest contributors to the electricity bills.

The assessments provided direction on the type of energy efficiency projects the companies would embark on. Efficiency energy projects would include compressed air system optimisation, lighting, and energy awareness. The implementation of energy efficiency projects was re-evaluated later, in order to measure the benefits of energy efficiency to companies' electricity bills and the natural environment.

The assessment activities for data collection comprised the following:

- Inception, feedback and closure meetings;
- Walking through the plant, to understand operational and manufacturing processes;
- Energy audits;
- Electricity consumption data before and after implementation;
- Selection of energy projects implemented;
- Data analysis; and
- Reports.

3.4.3 Qualitative data collection

"*Qualitative methods generally aim to understand the experiences and attitudes of patients and the community*" (Bricki & Green 2007:2). A quota sample questionnaire was used for the collection of data. The sample size for the research was ten percent of the staff compliment in each company. The sample is a non-probability sample. The population of the sample include operational staff and management of automotive component manufacturing companies. One questionnaire was used for company management and operational staff (*see* Annexure A). The questionnaire assisted in evaluating the perceptions, concerns and appreciation of company employees, corresponding with implementing energy efficiency projects within the working environment (Bricki & Green, 2007:2).

A questionnaire was constructed using closed-ended questions and a few open-ended questions. The questionnaire for management and operational staff comprised seventeen questions, three of which were open-ended. The companies requested the researcher to provide the questionnaire to the foremen in the companies, for distribution to operational staff willing to complete the questionnaire. To ensure honest, management will not distribute the questionnaires. Once the questionnaires were completed, the researcher personally collected them from the companies.

Strengths of the mixed mode method

Researchers can collect both quantitative and qualitative data simultaneously, allowing for perspectives from each method, and providing the advantages of both. This method is familiar to many researchers, and has a shorter data collection time, when compared to sequential methods (Terrell, 2011).

Weaknesses of the mixed mode method

The data needs to be transformed, in order to allow integration during analysis. This may lead to issues in resolving discrepancies that occur between different data types. It requires a great deal of expertise and effort to study the phenomenon under consideration, using two different methods (Terrell, 2011).

3.5 Data Analysis

3.5.1 Quantitative data analysis

The quantitative data was analysed through the application of perusal of historical consumption, consisting of time-trending the production and electricity use data. The data was also used for tariff structure analysis, in order to do a retrospective comparison with alternative tariffs. The production and electricity data were used in a linear regression analysis, for energy model development, as well as baseload and specific consumption assessment.

The observed operational practices, together with recorded system load profiles, were used to estimate the specific equipment electricity use annual consumption costs. The load profiles also enabled one to relate production practice to electricity use, and identify wasteful practices and associated efficiency opportunities. The same load profile and consumption estimates were used to realistically quantify the efficiency savings.

3.5.2 Qualitative data analysis

Data from the questionnaire was analysed, using the A statistical software (SAS Enterprise Guide). Findings from the analysis will be presented in Chapter 4.

3.6 Data Collection Procedure

3.6.1 Assessment

These assessments were conducted using consultants with extensive knowledge of energy management and energy efficiency. The assessments consisted of evaluating the company's energy management practices, observing the operations on equipment that were significant electricity users, and performing sample system load profile measurements.

The scope of work for the assessment that was carried out, is outlined as follows:

- Evaluation of energy management practices assessment, using generic energy management questionnaires;
- Assessment of historical electricity consumption for the years 2008 to 2011, before implementation of energy efficiency projects, and 2011 to 2013, after the implementation of energy efficiency projects;

- Performing of operational electricity consumption measurements on the priority systems identified;
- Detailed observations on the key assessment areas from an operations and maintenance efficiency perspective;
- Performing a feasibility assessment of the identified energy efficiency projects;
- Report generation, presenting the findings of the assessment; and
- Assessment feedback meetings and presentations.

3.6.2 Questionnaire and determination of sample size

A questionnaire was developed for management and operational personnel. To ensure an appropriate sampling size at each company, the group numbers represented ten percent (10%) of the staff complement of each company.

3.7 Ethical Considerations

The researcher is a student at UNISA, and continues to be employed by the National Cleaner Production Centre (NCPC) based at the Council for Scientific and Industrial Research (CSIR). The NCPC engages with the automotive companies to take part in the Resource Efficiency Cleaner Production Programme. Through the CSIR, the NCPC signs an agreement with the companies in the form of a memorandum of agreement (MOA) which gives consent to the NCPC to gain access to both the company and its information.

With a letter of permission from the NCPC, the researcher gained consent to access the companies and their information, and the researcher had to sign a memorandum of confidential agreement with the CSIR (s*ee* Annexure C). The research study was also approved by the UNISA College of Agriculture and Environmental Sciences (CAES) Ethics Committee.

Figure 3.3 gives an illustration of ethical agreements:

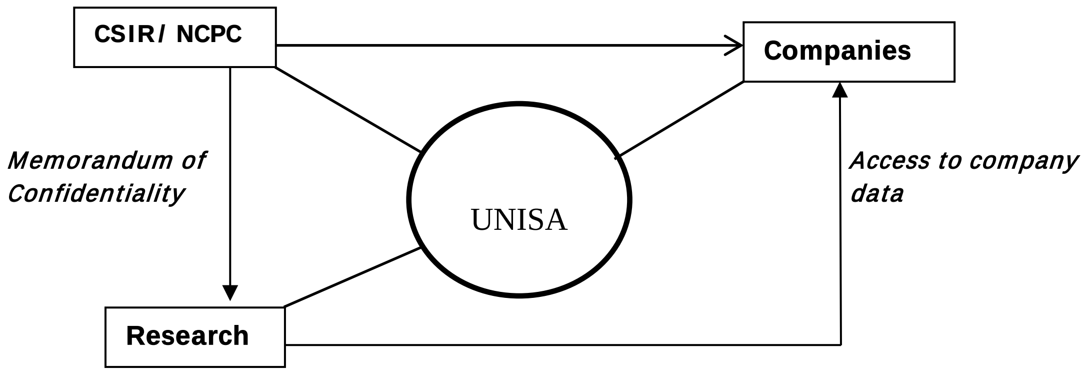

Figure 3.3: Ethical agreement flow diagram.

Source: Own.

The letter of permission for the University of South Africa (UNISA) ethics committe from the researcher's department at the Council for Scientific and Industrial Research (CSIR), stating all the above, was included in the ethics application (*see* Annexure C).

3.7.1 Confidentiality and anonymity

For confidentiality purposes, the companies will be known as companies A, B and C. Automotive component suppliers in South Africa are limited, in order to protect the companies; there will therefore be no mention of components manufactured by the companies.

The researcher provided a verbal explanation to the companies, to ensure that they were fully informed on how to participate and complete the questionnaire, and also for consent from the participants. To ensure anonymity, participants were not identified by name. All the participants were either in management or operational positions.

The research information provided was inclusive of the following:

- The content of the questionnaire;
- The time it would take to complete the questionnaire;
- Participants were not obligated to complete the questionnaire, and at any time could withdraw from taking part;
- Participants were only allowed to sign the consent form when satisfied with the explanation (see Annexure B); and
- To ensure confidentiality, the questionnaires were stored in a locked cabinet, and research data was password protected.

3.8 Conclusion

The researcher used the mixed mode method for this study. Assessments were conducted by consultants with extensive energy management knowledge. Company production processes were evaluated in conjunction with company electricity bills. Questionnaires were distributed to the companies, and then collected by the researcher. The respondents were both company operational staff and management. (For a copy of the questionnaire, see Annexure A).

Permission was obtained from the CSIR, as well as from the companies to take part on the research study. Those who did not want to complete the questionnaire were respected in not doing so. Confidentiality was ensured during the research.

In Chapter 4, the research results will be discussed. The data analysis, and interpretation of the qualitative and the quantitative results, will be presented separately. The chapter will cover the results of both the energy assessments and the responses to the questionnaire.

Chapter 4

Research Results

4.1 *Introduction*

This chapter discusses the analysis and interpretation of the data collected from three automotive component companies. The qualitative and quantitative data will be analysed and interpreted separately. Different research instruments were applied for the collection and analysis of the data. For the qualitative data, questionnaires were used, and for the quantitative data, assessments were conducted at the participating companies.

4.2 *Factor analysis, Reliability and Validity*

4.2.1 Factor analysis

A factor analysis was conducted on the scale data to determine if the scale was unidimensional (one-dimensional). In order to determine the underlying constructs (group of variables which are highly correlated among themselves), factor analysis was performed, to determine the number of underlying factors:

A. The FACTOR Procedure

Table 4.1: Factor procedure.

Input Data Type	Raw Data
Number of Records Read	69
Number of Records Used	51
N for Significance Tests	51

Source: Own.

Table 4.1 shows that 18 of the 69 observations were deleted, due to the missing values.

Table 4.2: Eigenvalues.

Eigenvalues of the correlation matrix: Total = 15 average = 1				
	Eigenvalue	**Difference**	**Proportion**	**Cumulative**
1	3.672008	1.463924	0.2448	0.2448
2	2.208083	0.536122	0.1472	0.392
3	1.671961	0.187512	0.1115	0.5035
4	1.484449	0.38005	0.099	0.6024
5	1.104399	0.04882	0.0736	0.6761
6	1.055579	0.189408	0.0704	0.7464
7	0.866171	0.286207	0.0577	0.8042
8	0.579964	0.045924	0.0387	0.8428
9	0.53404	0.026528	0.0356	0.8784
10	0.507512	0.075493	0.0338	0.9123
11	0.432018	0.10938	0.0288	0.9411
12	0.322638	0.073943	0.0215	0.9626
13	0.248695	0.054369	0.0166	0.9792
14	0.194327	0.076171	0.013	0.9921
15	0.118156		0.0079	1

Source: Own.

Table 4.2 shows that the results of the first six eigenvalues account for 74.6% variability in the data. Thus, six factors will be retained.

Table 4.3: Factor pattern.

Factor Pattern						
	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6
Energy_Projects	-0.00552	0.42466	0.45413	0.45209	0.09926	-0.38594
Energy_Efficiency_Understanding	-0.06044	-0.2957	-0.51786	0.49844	-0.12144	-0.17124
Energy_Knowledge_Action	-0.0788	-0.42864	0.50789	0.044	0.48411	0.09338
Efficiency_Job_Responsibility	0.0202	0.63108	0.38105	0.4814	-0.09677	0.06207
Dedicated_energy_team	-0.19479	-0.24063	0.01786	0.3694	0.06837	0.8029
Energy_targets_Company	0.73275	-0.28015	-0.22934	-0.03675	0.11074	-0.04155
Role_Project_demonstrated	0.68716	0.02747	-0.46871	0.27529	0.06217	0.03095
Role_Energy_Savings	-0.44325	0.55459	-0.28126	-0.2607	0.17655	0.29629
Target_Energy_Savings	-0.53799	0.52686	-0.07132	-0.08623	0.37259	0.00027
Training_Energy_Efficiency	0.71452	0.03368	0.41979	0.05857	-0.10967	0.21192
Energy_awareness_campaigns	0.65984	0.23292	-0.0067	-0.42251	0.28236	-0.12168
Communication_Energy_targets	0.68224	0.31478	-0.02339	-0.30339	0.14347	0.1981
Recognise_Savings_Efforts	0.63479	0.15029	0.29409	-0.07666	-0.43972	0.13751
Project_Implementation_involveme	-0.55067	-0.08681	0.16649	-0.45712	-0.54069	0.02548
Energy_Savings_Schemes_Home	0.10571	0.67189	-0.38285	0.14182	-0.21733	0.10532

Source: Own.

Table 4.4: Variances of factors.

Variance Explained by Each Factor					
Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
3.6720075	2.2080833	1.6719612	1.4844494	1.1043991	1.0555790

Source: Own.

Table 4.4 shows the variance explained by each factor. All factors are interpreted below.

Factor Analysis Interpretation

Variables with loadings lower than 0.3 are considered to have a non-significant impact on a factor, and can thus be ignored.

For Factor 1, the following variables (items) have large positive loadings: 'energy targets company', 'role project demonstrated', 'training energy efficiency', 'energy awareness campaigns', 'communication energy targets' and 'recognise savings efforts'. This factor may be labelled 'Energy savings communication'.

For Factor 2, the following variables have large positive loadings: 'efficiency job responsibility', 'energy savings schemes home', 'role energy savings', and 'target energy savings'. This factor may be labelled 'Energy savings efficiency'.

Factor 3 has relatively high positive loadings on 'energy projects', 'putting energy knowledge into action' and 'training energy efficiency'.

Factor 4 has large positive loadings on 'energy projects', 'energy efficiency understanding', 'efficiency job responsibility' and 'dedicated energy team'.

Factor 5 has large positive loadings on 'energy knowledge action' and 'target energy savings'.

Factor 6 has large positive loadings on 'dedicated energy team'.

4.2.2 Reliability

A questionnaire is considered reliable if the same results are obtained when the questionnaire is administered repeatedly. To assess the reliability of the questionnaire, one uses a measure of "internal consistency". This is the most common approach applied to groups of items or words that are thought to measure different aspects of the same concept.

Cronbach's coefficient alpha measures internal consistency reliability among a group of items combined to form a single scale. It is a reflection of how well the different items complement each other in their measurement of different aspects of the same variable or quality. It is interpreted that a correlation coefficient of ≥0.70 is good.

Scale: Factor 1

Table 4.5: Factor 1 – Simple statistics.

Simple Statistics						
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Min**	**Max**
Energy_targets_Company	60	3.75	1.27059	225	1	5
Role_Project_demonstrated	60	3.13333	1.51228	188	1	5
Training_Energy_Efficiency	60	3.1	1.18893	186	1	5
Energy_awareness_campaigns	60	3.58333	0.97931	215	1	5
Communication_Energy_targets	60	3.41667	1.09377	205	1	5
Recognise_Savings_Efforts	60	2.56667	1.4186	154	1	5

Source: Own.

From Table 4.5, it is evident that all items except "Recognise_Savings_Efforts" centre at the middle of the range. It is also noted that there are differences in the variability in items, but all have enough variation to be useful.

Table 4.6: Factor 1 – Cronbach's coefficient alpha.

Cronbach's Coefficient Alpha	
Variables	**Alpha**
Raw	0.81345
Standardised	0.821593

Source: Own.

Table 4.7: Factor 1 – Deleted variables.

Cronbach's Coefficient Alpha with Deleted Variable				
Deleted	**Raw Variables**		**Standardised Variables**	
Variable	**Correlation with Total**	**Alpha**	**Correlation with Total**	**Alpha**
F1A. I am aware of the energy targets of the company	0.574835	0.784127	0.569375	0.797012
F1B. Your role in the project was clearly explained and demonstrated to you	0.575767	0.787963	0.569953	0.79689
F1C. The level of training relating to energy efficiency	0.652197	0.768076	0.640828	0.781664
F1D: The energy efficiency awareness campaigns at the workplace	0.537403	0.794453	0.55561	0.799914
F1E: The communication of energy targets and savings achieved at the workplace	0.636933	0.77365	0.65598	0.778348
F1F: Individuals are recognised for their efforts in energy saving	0.530698	0.796547	0.532801	0.804686

Source: Own.

Cronbach's Alpha is given for "Raw" and "Standardised" scale. "Raw" is a scale that is constructed by adding the above six variables together. "Standardised" is a scale constructed by z-scoring each of the variables, then summing. Items that have more variability in the "Raw" scale contribute more to the variability of the resulting scale. In the "Standardised" scale, each variable has equal weight. Since the variables are measured on the same scale, and the standard deviations do not differ that much, it makes no difference which alpha is used (SAS, 2016).

In Table 4.7, the alpha coefficient for the six items is 0.81 (Raw) and 0.82 (Standardised), suggesting that the items have relatively high internal consistency – which is good when one considers 0.70 to be the cut-off value for being acceptable.

Scale: Factor 2

Table 4.8: Factor 2 simple statistics.

Simple Statistics						
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Min**	**Max**
Efficiency_Job_Responsibility	62	2.17742	1.55262	135	1	5
Energy_Savings_Schemes_Home	62	0.87097	0.33797	54	0	1
Role_Energy_Savings	62	1.80645	0.3983	112	1	2
Target_Energy_Savings	62	1.80645	0.3983	112	1	2

Source: Own.

Table 4.9: Factor 2 – Cronbach's coefficient alpha.

Cronbach's Coefficient Alpha	
Variables	**Alpha**
Raw	0.318966
Standardised	0.57107

Source: Own.

Table 4.10: Factor 2 – Deleted variables.

Cronbach's Coefficient Alpha with Deleted Variables				
Deleted Variable	**Raw Variables**		**Standardised Variables**	
	Correlation with Total	**Alpha**	**Correlation with Total**	**Alpha**
F2A: Energy efficiency is not part of my job responsibility	0.233573	0.591988	0.243377	0.58487

F2B: Do you have any energy-saving schemes at home	0.362105	0.215193	0.364519	0.490467
F2C: Your role in terms of energy savings has been written into your job description	0.234525	0.257975	0.418669	0.445404
F2D: I am aware of the targets of the company	0.283129	0.232326	0.394329	0.465884

Source: Own.

Tables 4.8 to 4.10 show that since Factor 2 is a mixture of dichotomous and multi-point scales in the survey, one has relatively heterogeneous variances; as such, one uses the standardised variables.

The output has an overall standardised alpha of 0.57 – which is accepted, but not with too much enthusiasm, if 0.7 is considered to be an acceptable reliability coefficient. Please note that some literature sometimes uses lower thresholds.

The table indicates that if F2A were to be deleted, then the value of the standardised alpha would increase from 0.57 to 0.58. It is also noted that the same variable has the lowest item-total correlation value (0.243377), which indicates that the F2A is not measuring the same factor that the rest of the items in the scale are measuring. Thus, the removal of F2A from the scale (factor) will make Factor 2 more reliable.

Scale: Factor 3

Table 4.11: Factor 3 – Simple statistics.

Simple Statistics						
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Min**	**Max**
Energy_Projects	61	1.37705	0.71096	84	1	5
Energy_Efficiency_Understanding	61	4.55738	1.04123	278	1	5
Training_Energy_Efficiency	61	3.04918	1.11693	186	1	5

Source: Own.

Table 4.12: Factor 3 – Cronbach's coefficient alpha.

Cronbach's Coefficient Alpha	
Variables	**Alpha**
Raw	0.023882
Standardised	0.097958

Source: Own.

Table 4.13: Factor 3 – Deleted variables.

Cronbach's Coefficient Alpha with Deleted Variable				
Deleted	**Raw Variables**		**Standardised Va riables**	
Variable	**Correla tion with Total**	**Alpha**	**Correlat ion with Total**	**Alpha**
Energy_Projects	0.20094 3	- 0.360 1	0.19802 4	- 0.361 114
Energy_Efficiency_Und erstanding	- 0.08378 3	0.288 61	-0.05281	0.313 861
Training_Energy_Efficie ncy	- 0.02066 4	0.125 04	0.02267 8	0.133 637

Source: Own.

Table 4.14: Factor 3 – Pearson correlation coefficients.

Pearson Correlation Coefficients, N = 61 Prob > |r| under H0: Rho=0			
	Energy_Projects	**Energy_Efficiency _Understanding**	**Training_Energy _Efficiency**
Energy_Projects	1	0.0716	0.18614
		0.5834	0.1509
Energy_Efficiency_Un derstanding	0.0716	1	-0.15294
	0.5834		0.2393
Training_Energy_Effic iency	0.18614	-0.1529	1
	0.1509	0.2393	

Source: Own.

Tables 4.11 to 4.14 show that the overall standardised alpha is very low (0.097958). This is due to the fact that the items/variables in this scale/factor are not correlated.

Scale: Factor 4

Table 4.15: Factor 4 – Simple statistics.

Simple Statistics						
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Min**	**Max**
Energy_ Projects	63	1.36508	0.70257	86	1	5
Energy_Efficiency_Understanding	63	4.63492	0.92111	292	1	5
Efficiency_Job_Responsibility	63	2.14286	1.52249	135	1	5
Dedicated_energy_team	63	2.57143	1.48882	162	1	5

Source: Own.

Table 4.16: Factor 4 – Cronbach's coefficient alpha.

Cronbach's Coefficient Alpha	
Variables	**Alpha**
Raw	0.090427
Standardised	0.14154

Source: Own.

Table 4.17: Factor 4 – Deleted variables.

Cronbach's Coefficient Alpha with Deleted Variable				
Deleted	**Raw Variables**		**Standardized Variables**	
Variable	**Correlation with Total**	**Alpha**	**Correlation with Total**	**Alpha**
F4A: The energy efficiency projects at our workplace are a waste of time and money	0.190986	-0.053186	0.176747	-0.064887
F4B: I understand what energy efficiency is	-0.030917	0.150852	-0.014038	0.224411
F4C: Energy efficiency is not part of my job responsibilities	0.004564	0.151533	0.040491	0.147565
F4D: A dedicated energy team must be appointed to focus on energy, so I can focus on my daily work	0.060842	0.031032	0.071247	0.102215

Source: Own

Scale

Tables 4.15 to 4.18 show that the overall standardised alpha is very low (0.14154); this is due to the fact that the items/variables in this scale/factor are not correlated.

Table 4.18: Factor 4 – Pearson correlation coefficients.

Pearson Correlation Coefficients, N = 63				
Prob > |r| under H0: Rho=0				
	Energy_Water_Projects	Energy_Efficiency_Understanding	Efficiency_Job_Responsibility	Dedicated_energy_team
Energy_Water_Projects	1	0.03481	0.26711	-0.0022
		0.7865	0.0343	0.9863
Energy_Efficiency_Understanding	0.03481	1	-0.19223	0.13105
	0.7865		0.1312	0.3059
Efficiency_Job_Responsibility	0.26711	-0.19223	1	-0.00102
	0.0343	0.1312		0.9937
Dedicated_energy_team	-0.0022	0.13105	-0.00102	1
	0.9863	0.3059	0.9937	

Source: Own.

Scale: Factor 5 and Factor 6

Factor 5 has relatively high positive loadings on only two variables which are not correlated at all – thus resulting in a very low Cronbach's alpha.

Factor 6 mainly represents a dedicated energy team which needs to be appointed to focus on energy efficiency.

Overall Cronbach's alpha:

Table 4.19: Overall simple statistics.

Simple Statistics							
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
Energy_Water_Projects	51	1.27451	0.49309	65	1	3	
Energy_Efficiency_Understanding	51	4.58824	0.98339	234	1	5	
Energy_Knowledge_Action	51	1.15686	0.64413	59	1	4	
Efficiency_Job_Responsibility	51	2.21569	1.56606	113	1	5	
Dedicated_energy_team	51	2.4902	1.50163	127	1	5	
Energy_targets_Company	51	3.7451	1.27817	191	1	5	
Role_Project_demonstrated	51	3.03922	1.48271	155	1	5	
Role_Energy_Savings	51	1.76471	0.4284	90	1	2	
Target_Energy_Savings	51	1.80392	0.40098	92	1	2	
Training_Energy_Efficiency	51	3.03922	1.11285	155	1	5	
Energy_awareness_campaigns	51	3.54902	0.94475	181	1	5	
Communication_Energy_targets	51	3.37255	1.11285	172	1	5	
Recognise_Savings_Efforts	51	2.45098	1.39016	125	1	5	
Project_Implementation_involveme	51	1.39216	0.49309	71	1	2	
Energy_Savings_Schemes_Home	51	0.86275	0.34754	44	0	1	

Source: Own.

Table 4.20: Overall Cronbach's coefficient alpha.

Cronbach's Coefficient Alpha	
Variables	Alpha
Raw	0.375818
Standardised	0.145305

Source: Own.

Discussion

Results for tables 4.19 to 4.20 show that the reliability of the scales (questionnaire) ranged from poor (low Cronbach' s alpha) to very good reliability (high Cronbach's alpha). There were high inter-item correlations among some items, while there were no correlations at all among other items. Some variables had very low item-total correlation value. This implies that some of the variables did not measure the same construct (factor) as the rest of the items in the scale were measuring. For scales that showed poor reliability, the individual items within the scale were supposed to have been re-examined and modified.

4.2.3 Validity

This refers to the extent to which a questionnaire measures what it purports to measure. The construct validity of the questionnaire was tested with factor analyses which were performed on the data, hence it could be concluded that the questionnaire was valid (NSSE, 2016).

4.3 Qualitative Data Analysis

The research was conducted to determine the perceptions that management and operational staff have towards the implementation of energy efficiency projects within the companies. Sixty-nine (69) completed questionnaires were received from all three companies. To obtain better results, the questionnaires from operational staff were analysed together, and the same was done with the management questionnaires. The sample of the research was ten percent (10%) of each company staff complement. Company A and Company B questionnaires, from management and operational staff, were completed. During the research, Company C was going through a change of management process, thus no questionnaires were completed or received from Company C's management.

During the completing of questionnaire, an annual automotive industrial action took place; resulting in all three companies requesting that all research activities stop as it was not safe to be at the company sites. This decision had an impact on the number of participants who completed the questionnaire and the employees deciding not to complete the questionnaire.

4.3.1 The objectives of the qualitative research

- To determine whether there was a shared understanding within operational staff and management on the implementation of energy efficiency projects; and

- To measure the difference in perceptions between management and operational staff on the implementation.

4.3.2 Data analysis

Statistical software (SAS Enterprise Guide) was used for the data analysis. The questionnaire was designed using two types of 5-point Likert scales, where 5 equals Strongly Agree, 1 equals Strongly Disagree, 5- equals Very Good, and 1 equals Very Poor. Other questions required either 'yes' or 'no' responses.

Questions posed to staff for the 5-point Likert scale included the following:

- I understand what energy efficiency is.
- Energy efficiency is not part of my job responsibilities.
- The energy efficiency projects at our workplace are a waste of time and money.
- Your role in the project was clearly explained and demonstrated to you.
- Your role in terms of energy savings has been written into your job description.

Typical questions asked for 'yes' or 'no' questions included the following:

- Have you been involved in implementation of energy efficiency projects?
- Your role in terms of energy savings has been written into your job description.

- You have been given targets for your specific work relating to energy savings.

4.3.3 Data presentation

Some of the participants did not answer all the questions. The weight average of both operational staff and managers was considered to measure the difference in their responses to similar questions.

Data presentation is divided into five sections.

A. Respondent profile;

B. Energy efficiency understanding and implementation;

C. Energy efficiency and project implementation correlation for managers;

D. Energy efficiency and project implementation correlation for operational staff; and

E. Conclusion in mean scores.

Section A: Respondent profile

Company A had the questionnaire's highest responses. Figure 4.1, below, demonstrates the averages of the questionnaires received, Company A contributing 73.91% of questionnaires received, Company B 15.94%, and Company C 10.14%.

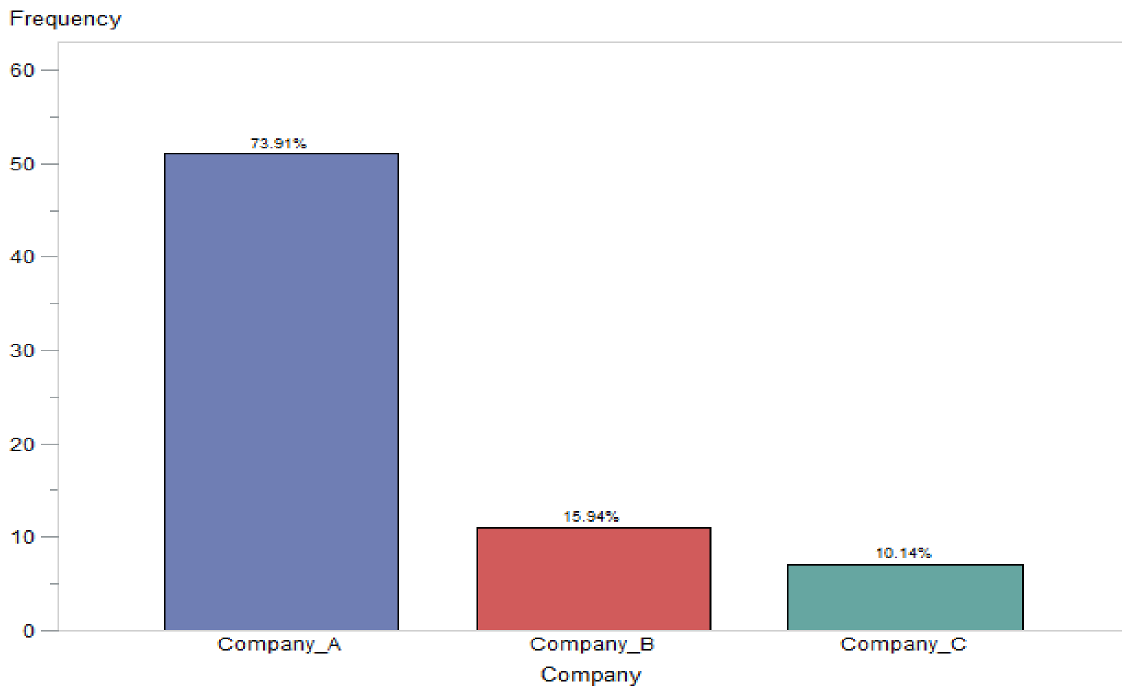

Figure 4.1: Average of company respondents on received questionnaire.

Source: Own.

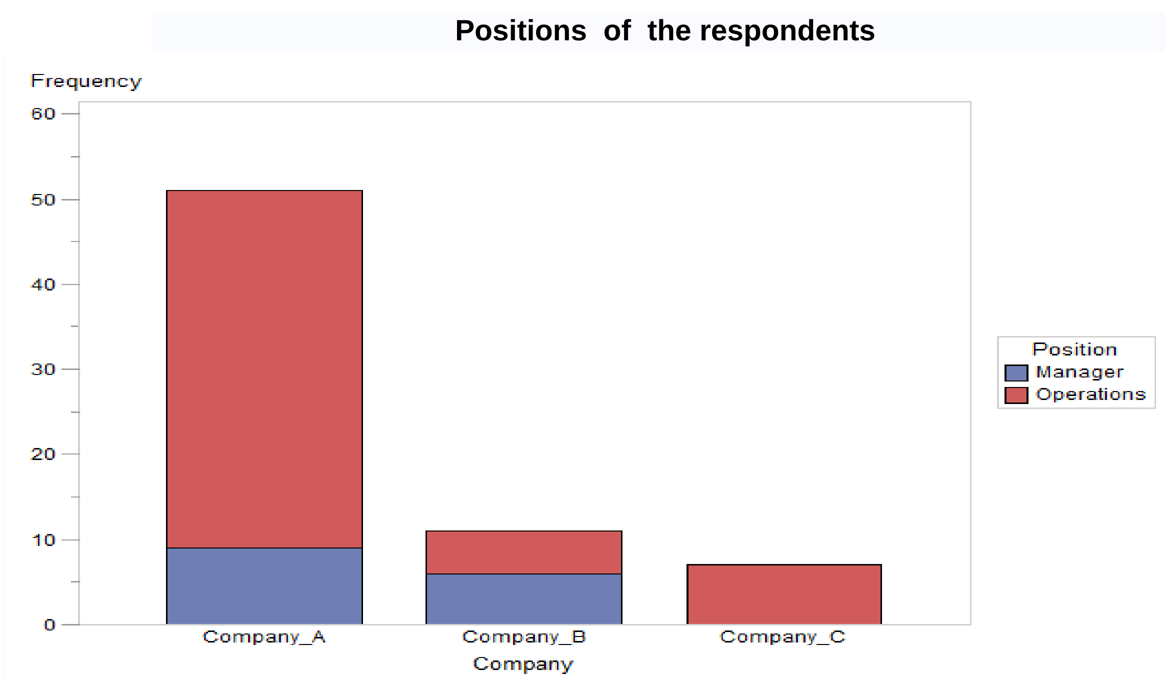

Figure 4.2: Average of company respondents per position.

Source: Own.

Company A respondents comprised operational staff, and the rest were managers. This was expected, as in most companies there are more operational positions than management. Company B managers responded more than did operational staff, and in Company C no managers responded.

Table 4.21: Frequency of respondents.

Position	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Manager	15	21.74	15	21.74
Operational staff	54	78.26	69	100.00

Source: Own.

Table 4.21 shows the frequency of the respondents: 15 managers and 54 operational staff responded to the questionnaire.

Section B: Energy efficiency understanding and implementation

To measure the shared understanding between operational staff and managers, the questionnaires were analysed, and the responses illustrated below.

1. I understand what energy efficiency is.

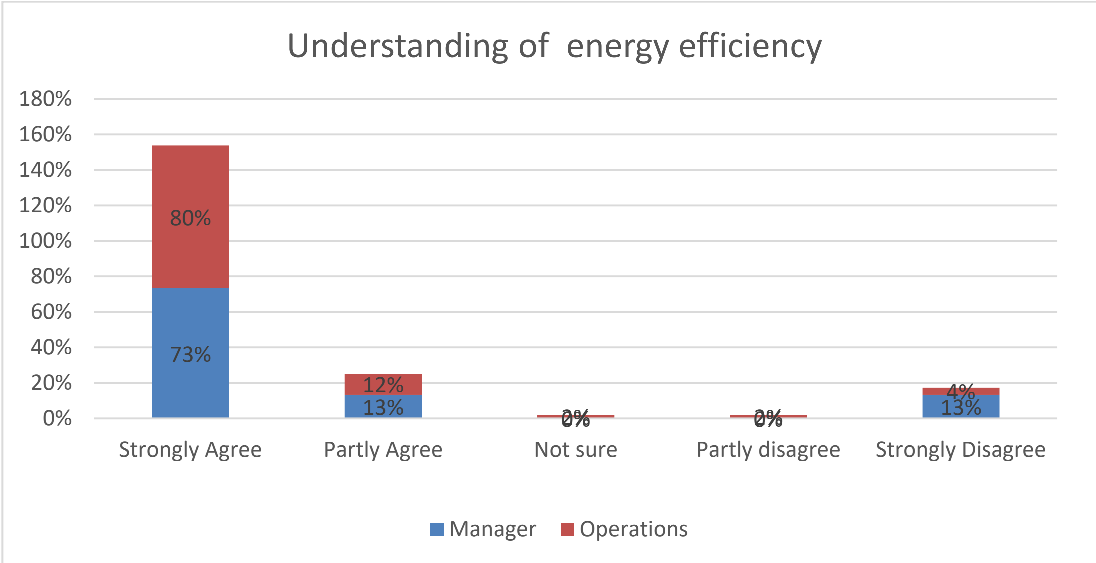

Figure 4.3: Energy efficiency understanding.

Source: Own.

There was no significant difference in the responses of operational staff and managers. Both parties either partly agreed or strongly agreed that they understand what energy efficiency is.

2. Where do you put your energy knowledge into action?

Table 4.22: Energy knowledge.

Energy knowledge action	Manager	Operational staff	Grand Total
I routinely try to save energy both at home and at work	14	50	**64**
I focus my efforts on saving energy at home and at work	0	0	**0**
I focus my efforts on saving energy at work	1	1	**2**
I don't usually think about trying to save energy	0	3	**3**
Grand Total	**15**	**54**	**69**

Source: Own.

The majority of respondents, both on operational and management level, said that they routinely try to save energy both at home and at work.

3. Energy efficiency is not part of my job responsibilities.

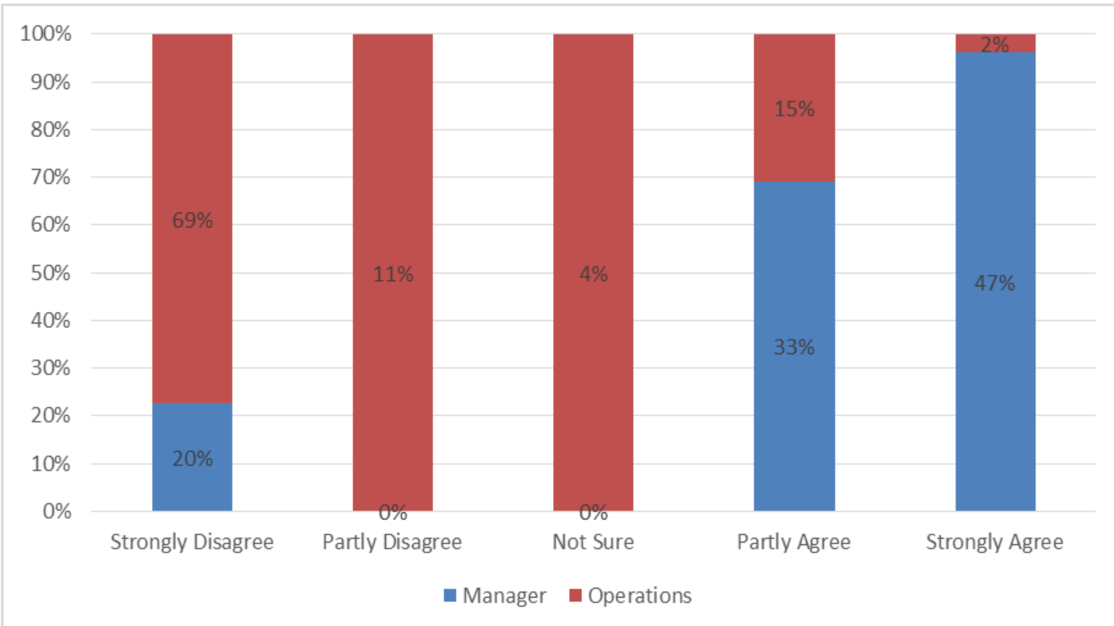

Figure 4.4: Energy efficiency not a job responsibility.

Source: Own.

Eighty percent (80%) of the managers agreed that energy efficiency is not part of their job responsibilities, while 80% of operational staff said that energy efficiency does form part of their job responsibilities.

4. A dedicated energy team must be appointed to focus on energy, so I can focus on my daily work.

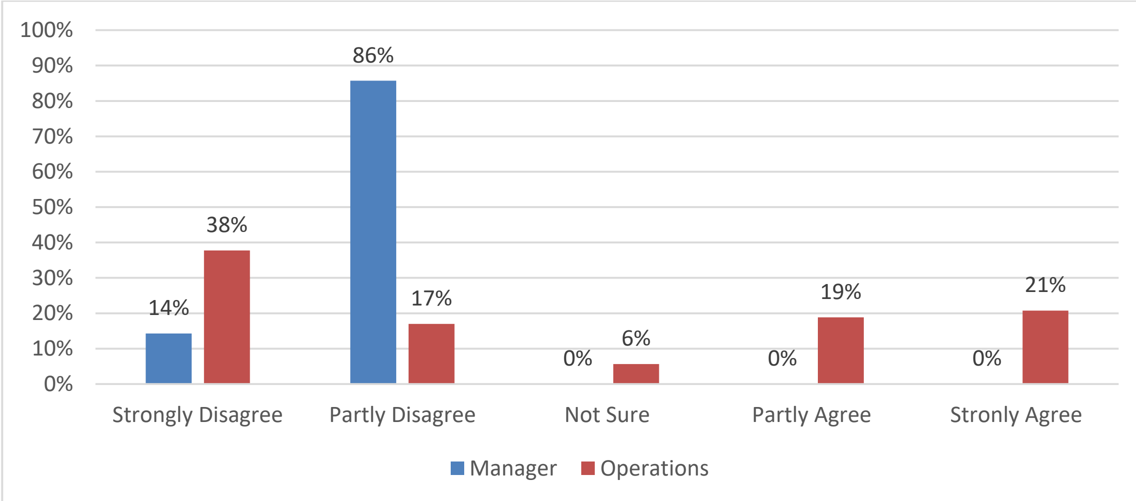

Figure 4.5: Appoint a dedicated energy team.

Source: Own.

Table 4.23: Appoint dedicated energy team.

A dedicated team must be appointed to focus on energy	**Manager**	**Operational staff**	**Grand Total**
Strongly Disagree	2	20	22
Partly Disagree	12	9	21
Not Sure	0	3	3
Partly Agree	0	10	10
Strongly Agree	0	11	11
No answer	1	1	2
Valid Total	14	53	67
Grand Total	**15**	**54**	**69**

Source: Own.

From Table 4.23, it is evident that managers disagreed that a dedicated energy team must be appointed to focus on energy, while 40% of operational staff did agree that a dedicated energy team must be appointed. One manager did not respond to the questionnaire.

5. The energy efficiency projects at our workplace are a waste of time and money.

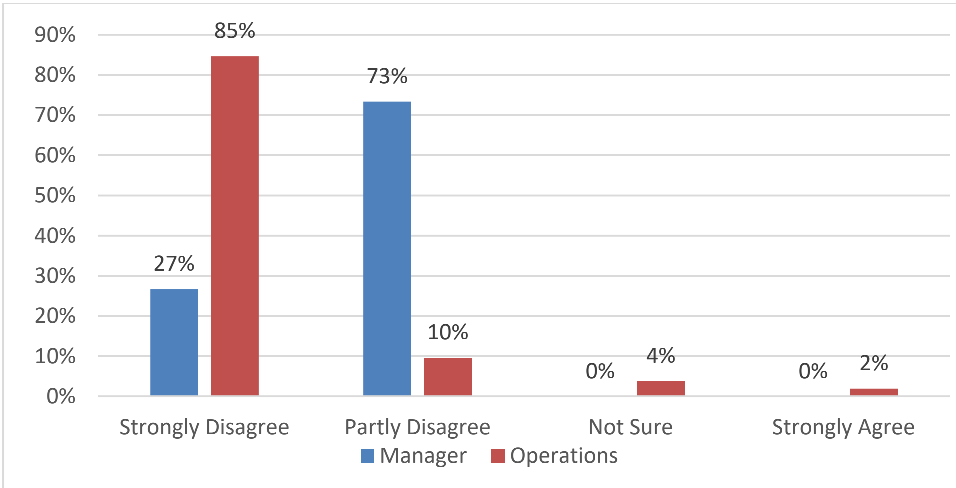

Figure 4.6: Energy efficiency projects a waste of time.

Source: Own.

There was a shared understanding from both operational staff and management, that projects are not a waste of time and money. They agreed that the projects are valuable at their workplaces.

6. I am aware of the energy targets of the company.

Table 4.24: Energy target awareness.

Aware of company target	Manager	Operational staff	Grand Total
Strongly Disagree	1	6	7
Partly Disagree	2	4	6
Not Sure	4	12	16
Partly Agree	6	11	17
Strongly Agree	2	21	23
Grand Total	**15**	**54**	**69**

Source: Own.

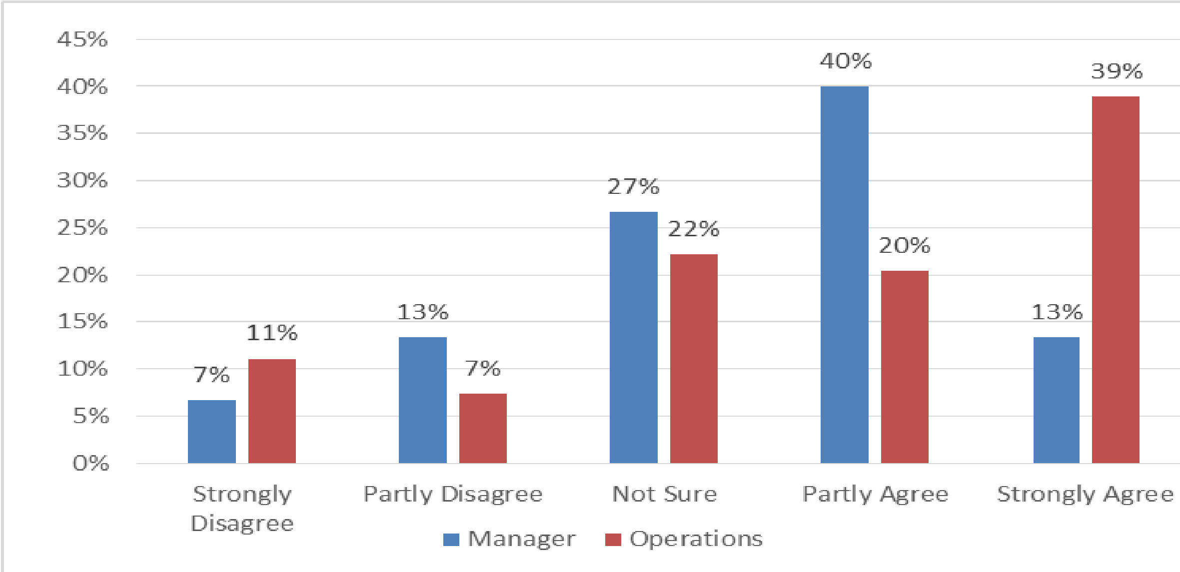

Figure 4.7: Awareness of energy targets.

Source: Own.

From Table 4.24 and Figure 4.7, it is evident that 59% of operational staff, and 53% of managers, respectively, said that they are aware of the energy targets of the company.

7. Have you been involved in implementation of energy efficiency projects?

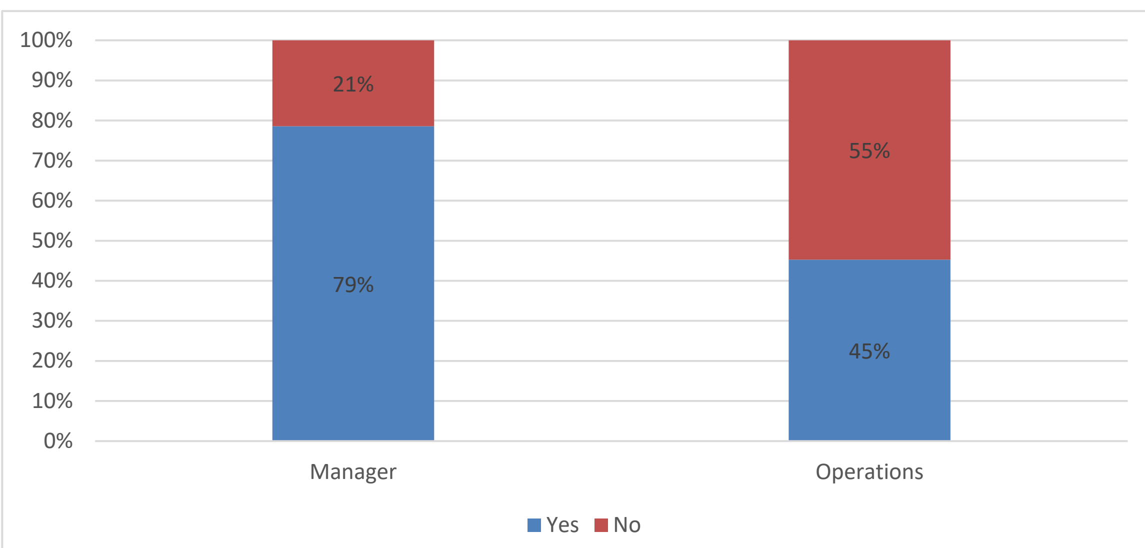

Figure 4.8: Involvement in implementation of energy efficiency projects.

Source: Own.

From Figure 4.8, it is evident that the majority of managers said that they had been involved in the implementation of energy efficiency projects, with only 45% of operational staff involved in the implementation.

8. Your role in the project was clearly explained and demonstrated to you.

Table 4.25: Role explained and demonstrated.

Role in project clearly explained and demonstrated	Manager	Operational staff	Grand Total
Disagree	4	21	25
Not Sure	2	3	5
Agree	9	24	33
No answer	0	6	6
Grand Total	15	54	69

Source: Own.

Table 4.25 demonstrated that all 24 members of operational staff, who said that they had been involved in the implementation of the projects at their workplace, agreed that their role, in terms of the project, had been clearly explained and demonstrated. Nine (9) of the 11 managers agreed that the role had been demonstrated, while two (2) of the managers were not sure, and four (4) disagreed. Six of the operational staff members did not provide their opinion.

9. Your role in terms of energy savings has been written into your job description.

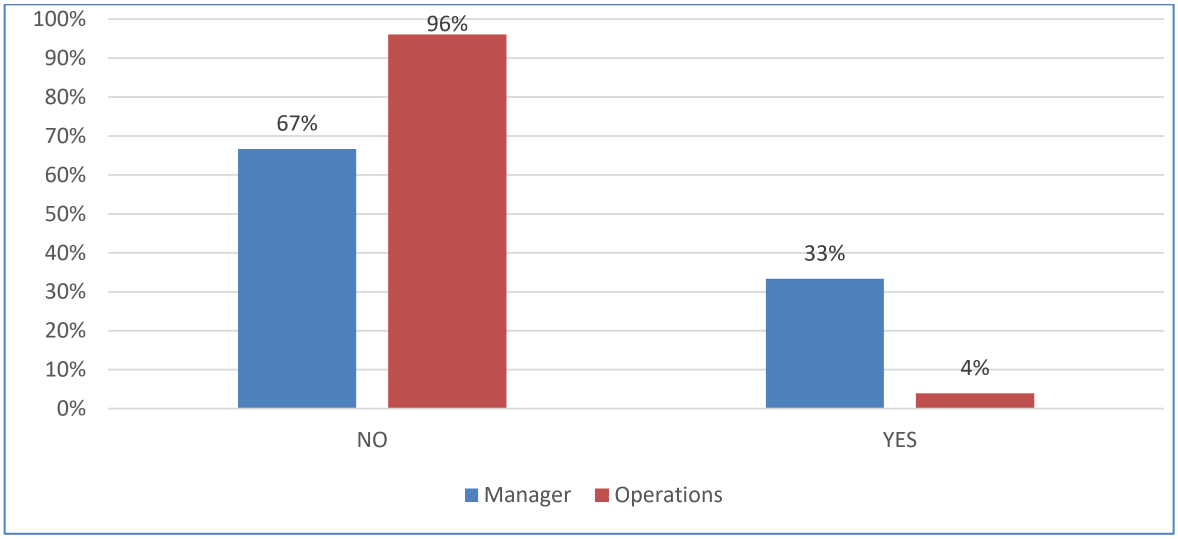

Figure 4.9: Role written into job description.

Source: Own.

From Figure 4.9, it is evident that 33% of managers have their role, in terms of energy savings, written into their job description, while 96% of operational staff does not have their role, in terms of energy, written into their job description.

10. You have been given targets for your specific work relating to energy savings.

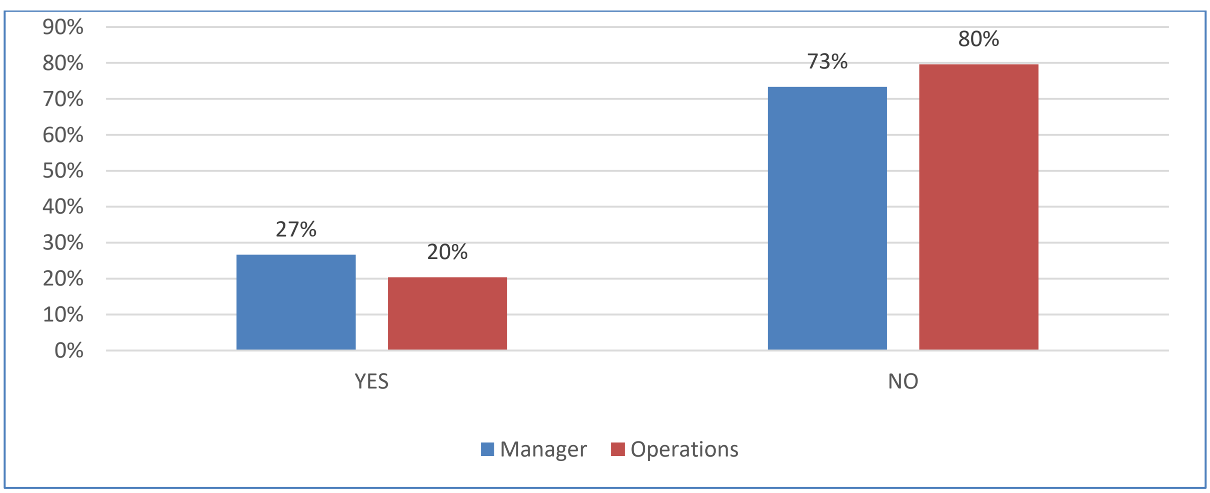

Figure 4.10: Energy savings targets given to specific staff members.

Source: Own.

From Figure 4.10, it is evident that only 27% of managers and 20% of operational staff said that they were given targets for their specific role relating to energy savings. Even though it is part of their job description, the rest of the operational staffs have no specific energy targets.

11. The level of training provided to you, relating to energy efficiency was ...

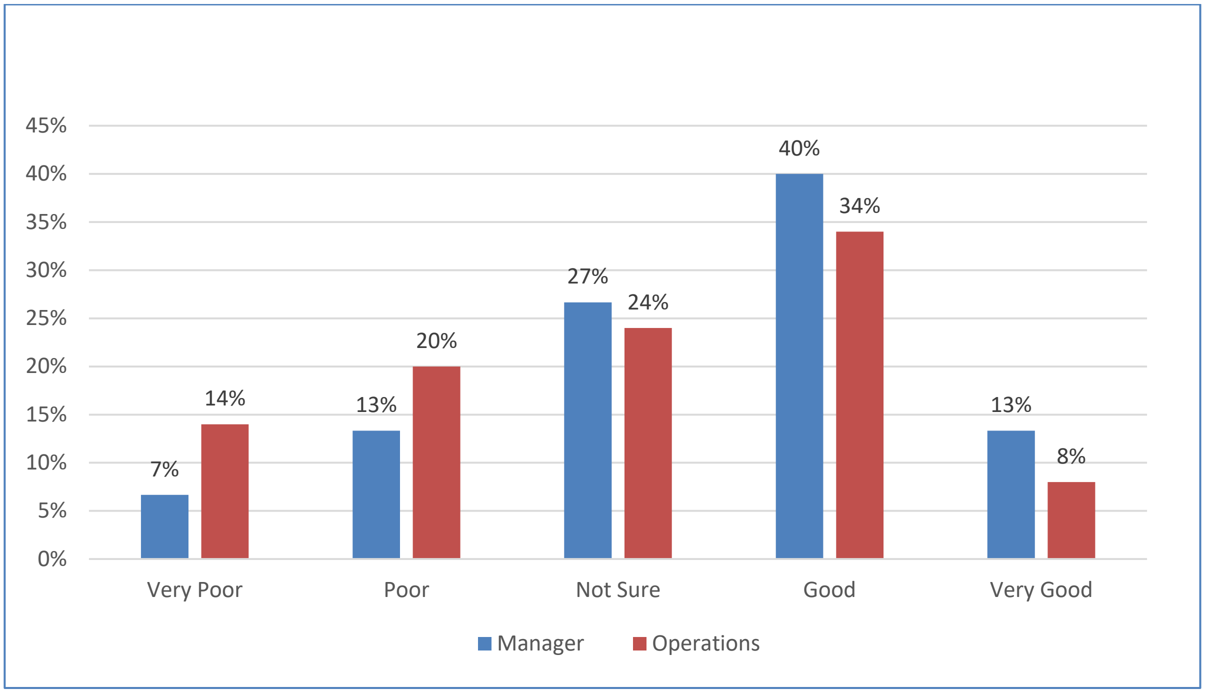

Figure 4.11: Training provided.

Source: Own.

From Figure 4.11, it is evident that 53% of the managers found the level of training relating to energy efficiency to be good, and 20% found it to be poor, while 27% were not sure. Less than half the operational staff found the level of energy training to be good, 34% found it poor, and 24% said they were not sure about the level of training received.

12. The energy efficiency awareness campaigns at the workplace are ...

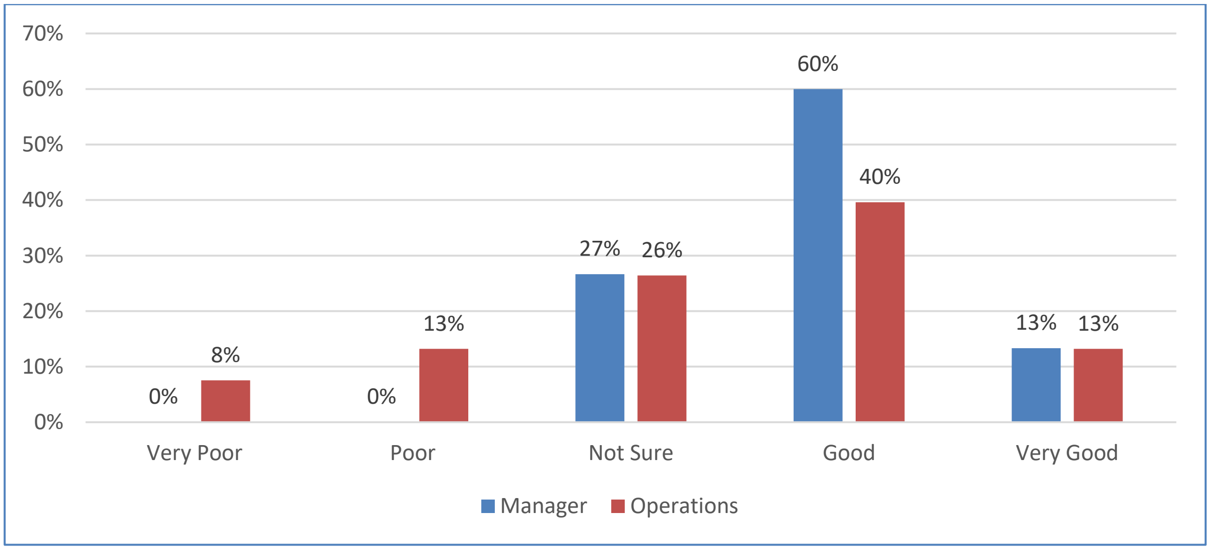

Figure 4.12: Energy efficiency campaigns at workplace.

Source: Own.

From Figure 4.12, it is evident that the majority of managers (73%) thought the energy efficiency awareness provided by the companies was good and very good. None thought the awareness was poor, even though 27% of the managers were unsure. In contrast, 53% of the operational staff found the energy efficiency awareness good, and 21% said it was poor, and were not sure.

13. The communication of energy targets and savings achieved at the workplace is ...

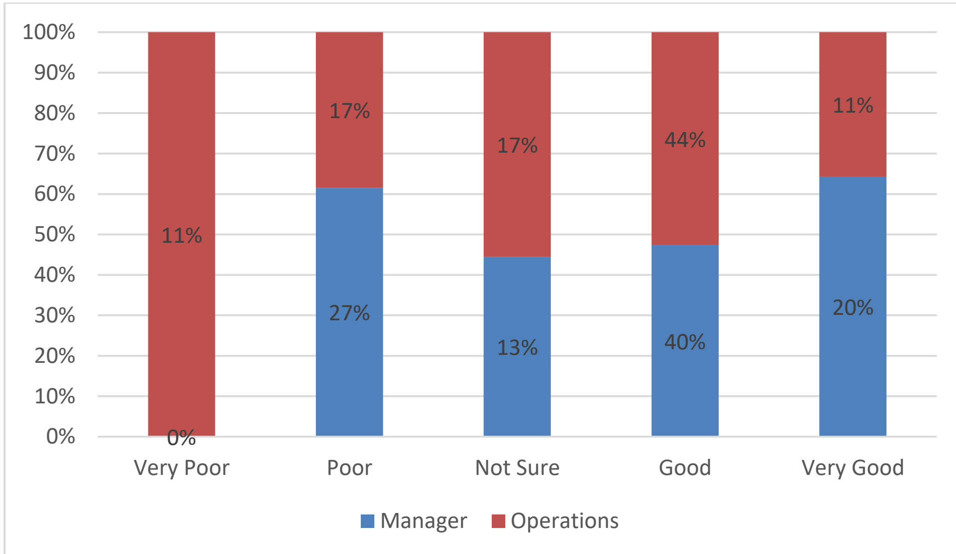

Figure 4.13: Communication of targets and achievements.

Source: Own.

From Figure 4.13, it is evident that 60% of managers and 55% operational staff said that they find the communication of energy targets and savings achieved at the workplace to be good. However, 11% of operational staff said that the communication is very poor.

14. Individuals are recognised for their energy-saving efforts.

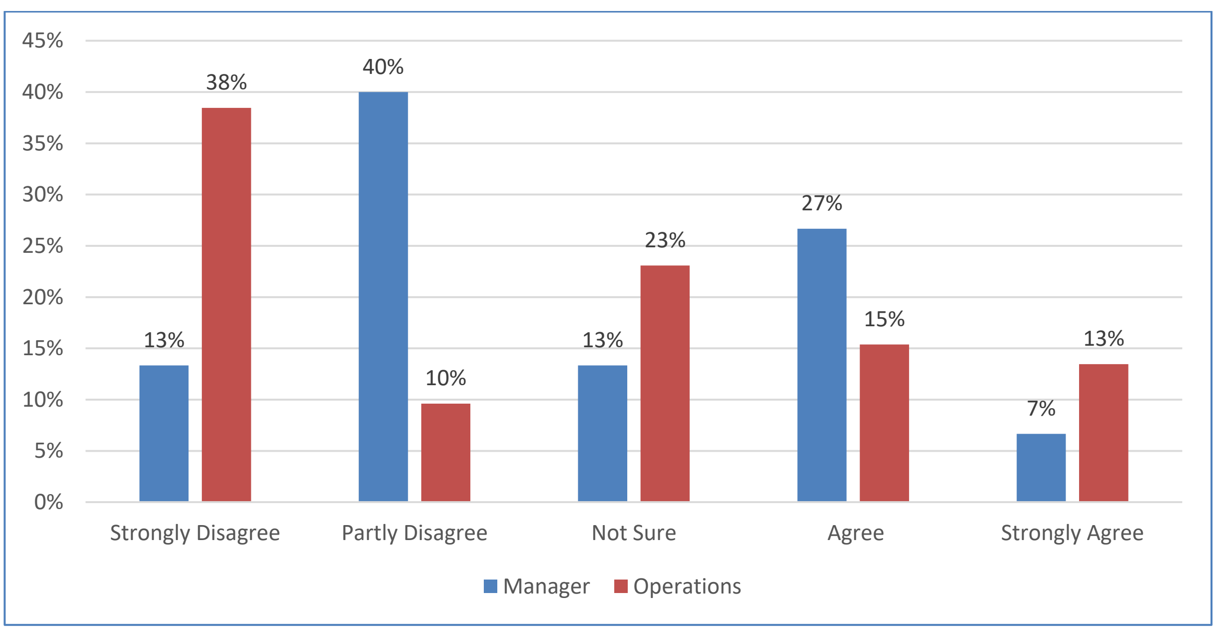

Figure 4.14: Recognition for energy-saving efforts.

Source: Own.

From Figure 4.14, it is evident that over 50% of both managers and operational staff disagree that individuals are recognised for their efforts in energy savings. This means that the employees feel that they are not being recognised for their efforts in energy savings. Others believe that there is some recognition for energy initiative, and the rest are not sure.

The following questions were open-ended questions; therefore, respondents were expected to give their answers according to their own understanding. The responses to this were clustered, and ranked according to the number of times they were said.

15. Which tasks form part of your daily routine, that contribute towards energy saving?

Table 4.26: Daily routine energy contribution.

Daily routine contributing to energy savings	**Count**
Switch off lights when machine is not running or when there is no production	18
Switch off all electric appliances	3
Switch off machines not in use	4
Report and repair water leaks, air leaks and oil leaks	6
Switching off distant units when not in use	2
Track the energy usage daily so that one can see the increase in consumption	2
Temperature controller on heaters	1
Take water readings at cooling power	1
Startup of manufacturing booth oven	1

Monitor boiler efficiency	1
Make sure that energy is used wisely	1
Control conductivity of energy that reduces energy consumption	1
Check on energy consumption	1
Boil only just enough water	1
Other	9

Source: Own.

Table 4.26 illustrates day-to-day activities undertaken by the respondents to contribute on the savings.

16. Can you think of two instances where the company is wasting energy?

Table 4.27: Company energy waste.

Company wasting energy	**Count**
24-hour lights in office and air-conditioner left on after hours	30
Leaking taps and toilets not reported and fixed	19
Office equipment running during break time, through the night, and being left on when not in use	5
Fans and heaters not monitored correctly	1
Incorrect elements fitted	1
Insulation of tanks and pipes	1
Compressor running for one machine	2
Water fountain not piped properly	1

Water fountain not cold water	1
Draining of pits too often	1
Other	10

Source: Own.

Table 4.27 shows examples of how companies waste energy.

17. Do you have any energy-saving schemes at home?

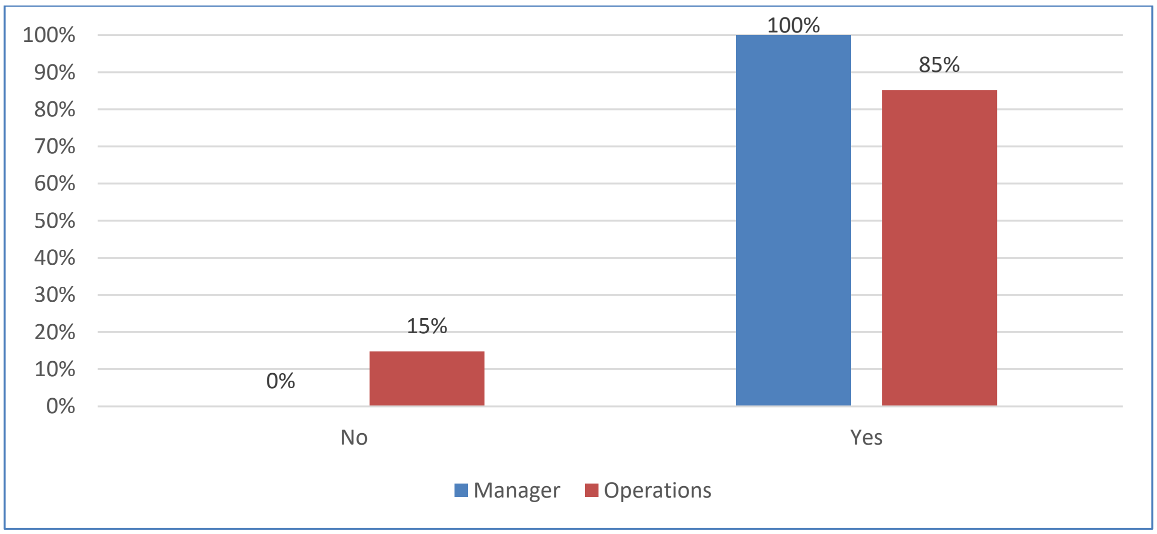

Figure 4.15: Energy-saving schemes at home.

Source: Own.

From Figure 4.15, it is evident that all the managers and the majority of operational staff do have energy-saving schemes at home.

18. List the three main savings schemes that you think save you the most.

Table 4.28: Listed energy schemes.

Home energy-saving schemes	Count
Use energy-saving bulbs and switch off lights that are not in use	46
Switch off geyser when not in use, set the geyser timer and use the geyser blankets	34
Switch off all electric appliances not in use and unplug all the plugs	15
Use the solar geyser	9
Boil only the amount of water needed	14
Use gas stove instead of electrical stove	11
Use heat pump for pools and switch off pool heat pump	12
Other	13

Source: Own.

From Table 4.28, it is evident that most company employees have implemented energy-saving schemes that include energy-saving bulbs and management of geysers.

Section C: Energy efficiency and project implementation correlation for managers

In this section, the relationship between the managers' perceptions with regard to energy efficiency and the energy efficiency projects implemented, is considered. A Pearson correlation coefficient was used to quantify the relationship. A Pearson correlation coefficient is used for measuring the strength of the linear relationship between two or more variables. The Pearson correlation coefficient can take a range of values from -1 to 1 with zero, meaning that there is no relationship between variables.

Table 4.29: Correlation efficiency.

Correlations coefficient	Interpretation
0 to 0.5	No relationship to a weak linear relationship (positive or negative)
0.5 to 0.7	Moderate linear relationship (positive or negative)
> 0.7	A strong linear relationship (positive or negative)

Source: Own.

Table 4.30: Correlation of managers.

	Variable 1	Variable 2	Correlation coefficient
1	Efficiency_Job_Responsibility	Energy_Knowledge_Action	-0.51089
2	Project_Implementation_Involvement	Energy_Knowledge_Action	0.53109
3	Energy_Knowledge_Action	Efficiency_Job_Responsibility	-0.51089
4	Energy_Targets_Company	Efficiency_Job_Responsibility	0.52532
5	Project_Implementation_Involvement	Efficiency_Job_Responsibility	-0.61342
6	Training_Energy_Efficiency	Efficiency_Job_Responsibility	0.52532
7	Role_Project_Demonstrated	Energy_ Projects	-0.53612
8	Communication_Energy_targets	Energy_ Projects	-0.53612
9	Efficiency_Job_Responsibility	Energy_Targets_Company	0.52532
10	Energy_Awareness_Campaigns	Energy_Targets_Company	0.57739

11	Recognise_Savings_Efforts	Energy_Targets_Company	0.70854
12	Target_Energy_Savings	Role_Project_Demonstrated	-0.53612
13	Energy_Awareness_Campaigns	Role_Project_Demonstrated	0.50249
14	Recognise_Savings_Efforts	Role_Project_Demonstrated	0.62975
15	Communication_Energy_Targets	Target_Energy_Savings	-0.53612
16	Energy_Awareness_Campaigns	Training_Energy_Efficiency	0.57739
17	Recognise_Savings_Efforts	Training_Energy_Efficiency	0.70854
18	Role_Project_Demonstrated	Energy_Awareness_Campaigns	0.50249
19	Communication_Energy_Targets	Energy_Awareness_Campaigns	0.50249
20	Recognise_Savings_Efforts	Energy_Awareness_Campaigns	0.68156
21	Communication_Energy_Targets	Recognise_Savings_Efforts	0.62975

Source: Own.

From Table 4.30, it is evident that among the managers whose role has been written into their job descriptions, energy use decreases, as they put energy knowledge into action. These managers said that they try to save energy both at home and at work.

The correlation of managers, Table 4.30, is highlighted in the statement below. The numbers in the statement refer to the row in the table. The managers who were involved in the energy efficiency projects implementation, try to save energy both at home and at work (1). The managers who were involved in the implementation of the energy efficiency projects, have their role in energy savings written into their job descriptions (6). The managers who agreed that the energy projects at their workplace are a waste of time and money, disagreed that their role in the project was clearly explained and demonstrated to them (7). In contrast, managers who said that the energy awareness campaigns at their workplaces were good, also said that the communication of energy targets and savings at their workplaces was good (10). In addition, managers who said the communication of energy targets and savings at their workplaces was good, were not given targets in their specific work relating to energy savings (15).

Managers who said that the energy awareness campaigns at their workplaces were good, also agreed that the level of training provided to them relating to energy efficiency, was also good (16). Managers who said that the communication of energy targets and savings at their workplaces was good, said that individuals are recognised for their efforts in energy savings (20).

Section D: Energy efficiency and project implementation correlation for operational staff

Table 4.31: Correlation of operational staff.

	Variable 1	Variable 2	Correlation coefficient
1	Energy_ Projects	Dedicated_Energy_team	0.71498
2	Role_Project_Demonstrated	Project_Implementation_Involvement	-0.65512
3	Target_Energy_Savings	Role_Energy_Savings	0.50244
4	Recognise_Savings_Efforts	Training_Energy_Efficiency	0.59714
5	Energy_Targets_Company	Energy_Awareness_Campaigns	0.50592
6	Communication_Energy_Targets	Energy_Awareness_Campaigns	0.79878
7	Energy_Targets_Company	Role_Project_Demonstrated	0.63716
8	Project_Implementation_Involvement	Role_Project_Demonstrated	-0.65512
9	Recognise_Savings_Efforts	Training_Energy_Efficiency	0.59714

Source: Own.

From Table 4.31, it is evident that the respondents working as operational staff, who said that the energy efficiency projects at their workplace are a waste of time and money, also said that a dedicated team must be appointed to focus on energy, so that they can focus on their daily work (1).

The operational staff who had been involved in the implementation of energy efficiency projects, said that their role in the project had not been clearly explained and demonstrated to them (2).

The respondents whose role, in terms of energy savings, had been written into their job description, were also given targets for their specific work relating to energy savings (3).

Operational staff who said that the energy efficiency awareness campaigns at their workplace was good, found that the communication of energy targets and savings achieved at their workplaces was very good (4). Operational staff who had been involved in energy efficiency project implementation, said that their role in the project had not been clearly explained and demonstrated to them (8).

E. Conclusion in mean scores for managers and operational staff

In this section, it is considered whether there is a significant difference in the perceptions of managers and employees, within the companies, with regard to the energy efficiency projects implemented.

Mean scores were computed, to determine whether the responses to questions/perceptions between the managers and operational staff were different. A mean score is the mean of a frequency table or a weighted average. It is used to measure how many times the respondents chose a certain option.

Table 4.32: Mean score example.

Response	**Number of respondents**
Strongly Disagree	2
Partly disagree	1
Not sure	1
Partly agree	6
Strongly agree	41
Not answered	3
Grand Total	54

Source: Own.

Table 4.32 shows that there were 41 operational staff, who strongly agreed with the statement, 'I understand what energy efficiency is', and two (2) staff members who said that they strongly disagreed with the statement.

Table 4.33: Mean score for managers and operational staff.

	Mean Scores	**Managers**	**Operational staff**
1	Energy_Efficiency_Understanding	4.3	4.4
2	Energy_Knowledge_Action	1.1	1.2
3	Efficiency_Job_Responsibility	3.9	1.7
4	Dedicated_Energy_Team	1.7	3.2
5	Energy_ Projects	1.7	1.2
6	Energy_Targets_Company	3.4	3.7
7	Project_Implementation_Involvement	1.1	1.5
8	Role_Project_Demonstrated	3.5	2.6
9	Role_Energy_Savings	1.7	1.7
10	Target_Energy_Savings	1.7	1.8
11	Training_Energy_Efficiency	3.4	2.8
12	Energy_Awareness_Campaigns	3.9	3.3
13	Communication_Energy_Targets	3.5	3.3

14	Recognise_Savings_Efforts	2.7	2.5
15	Energy_Savings_Schemes_Home	0.7	0.9

Source: Own.

Table 4.33 shows a difference in some of the perceptions between managers and operational staff.

Managers felt strongly that energy efficiency is not part of their job responsibilities, while operational staff said that energy efficiency is part of their job responsibility (3).

Managers did not agree that a dedicated energy team must be appointed to focus on energy, so they can focus on their daily work, while some operational staff agreed that a dedicated team must be appointed (4).

Operational staff did not agree that the energy efficiency projects at their workplace are a waste of time and money, while managers partly agreed that it is so (5).

Managers agreed that their role in the project was clearly explained and demonstrated, whereas operational staff did not agree (8).

Managers found the energy efficiency awareness campaigns at their workplace to be good, while the operational staff were not sure whether the campaigns are good or not (12).

The qualitative research findings outline that, 80% of the managers agree that energy efficiency is not part of their job responsibilities, while the 80% of operational staff said that energy efficiency does form part of their jobs. 33% of managers have their roles in terms of energy savings written into their job description, while 96% of operational staff do not know their role in terms of energy being written into their job description.

4.4 Quantitative Data Analysis

4.4.1 Implemented energy projects

The range of energy efficiency projects identified by the researcher varied from the low 20s to above 40, demonstrating that a wide variety of opportunities exist within manufacturing companies, depending on their particular production processes and equipment. At the time of study, the fraction of implemented projects averaged 52%, with the lowest fraction being 46% with a range of 14%. From this figure it can be concluded that roughly 50% of the identified energy efficiency opportunities are implemented by assessed companies within the first year.

Some of the energy projects implemented by the three automotive component manufacturing companies are shown in Table 4.14, demonstrating the wide variety of manufacturing energy efficiency options:

Table 4.34: List of implemented efficiency projects.

Number	Implemented Project	Projected Energy Savings [kWh per Year]	Projected Cost Savings [R per Year]
1.	Installation of Whirlybirds on Main Factory Roof	4 000	2 400
2.	Automate compressor on/off	34 000	20 500
3.	Change Hot-Water Geyser Settings	250	210
4.	Implement Daylight Harvesting	45 000	30 150

5.	Install VSD Controlled Compressor	153 250	102 700
6.	Install Power Factor Correction	-	102 000
7.	Install a New Energy-Efficient Chiller Plant	29 200	19 600
8.	Implement Tariff Structure Change	-	227 000
9.	Upgrade Boiler Insulation	32 000	21 400
10.	Repair Compressed Air Leaks	21 500	14 400
11.	Automate Cooling Tower Controls	46 400	27 500
12.	Install Energy-Efficient Lighting	93 000	62 200
13.	Reduce Furnace Start-Up Time from 24 hours to 8 hours	205 000	137 800
14.	Install Lids on Heated Process Tanks to reduce Evaporative Heat Loss	424 700	284 530
15.	Reduce Compressed Air Pressure Drops, and reset Compressor Pressure to 6.4 bar.	32 650	21 900
16.	Use an Electric Blower for agitating the Effluent Mixing Tank.	322 100	215 800
17.	Use Electric Blower for cooling Wire at MF2 scale breaker instead of Compressed Air.	279 750	187 430

Source: Own.

From Table 4.34, it is evident that the actual energy savings value of the implemented opportunities represents an average of 33% of the total value of the identified potential opportunities. This can be directly attributed to most implemented opportunities being low-moderate cost opportunities, which in some cases also have lower potential for energy consumption reductions. In the automotive component manufacturing companies, financial constraints, caused by a slowing local economy and increasing global competition, affected the choice of implemented projects, with cash-flow considerations in the minds of management.

Table 4.35: Energy efficiency projects implementation rate.

Company	Company A	Company B	Company C
Total Number of Identified EE Opportunities	42	18	22
Value of Identified Opportunities [kWh]	2616365	2733776	496815
Number of Implemented Projects	25	9	10
Fraction of Total Identified Projects	60%	50%	46%
Energy Savings of Implemented Opportunities [kWh]	875058	1297920	265950
Value of Implemented Savings	R 815, 546.00	R 869, 607.00	R 178, 186.50
Implemented Savings Fraction of Original	31%	32%	36%

Source: Own.

Table 4.35 shows the total number of energy efficiency opportunities that were identified at each of the three case study companies, and the projects that had been implemented at the time of the case study assessment.

4.4.2 Energy consumption and CO_2 reductions due to implemented energy efficiency projects

Energy Consumption Reduction

Table 4.36: Energy use changes.

	Company A	Company B	Company C
Production Change	-7%	-15%	15%
Energy Consumption Change	-1%	-4%	-20%
Energy Intensity Change	5%	-7%	-25%

Carbon Emissions (CO_2) Change	-1%	-4%	-20%

Source: Own.

From Table 4.36, it is evident that all the companies saw reductions in their energy consumption as a result of both energy efficiency and production changes. In two of the case studies, the companies experienced significant production output reductions due to market forces (15% and 7%, respectively). The reductions in energy consumption for these companies were factored out, and only the remaining energy use reductions were then attributed to the implemented energy efficiency measures.

The small energy consumption change seen for Company A, despite implementing the highest fraction of identified energy efficiency opportunities, can be attributed to changes in the production plant. The company commissioned additional production equipment, and also changed some production processes, with the commissioning of high energy consuming equipment. This change in processing was dictated by stringent quality requirements. The production level decreases were also accounted for, using the developed energy models. This resulted in low overall energy consumption changes, because of the production process and output changes. A new baseline, which considers the impact of these changes, will have to be developed for accurate energy efficiency performance reporting in the future.

Company B also experienced significant changes to its operations, including the decommissioning of entire production lines, and reduction in production times from three shifts to a single shift. Changes were also implemented in the production processes such as the furnace, where electrical heating replaced coal-fired steam heating. These changes offset some of the energy efficiency interventions, resulting in a diminished cumulative change due to EE project implementation.

In the case of Company C, increases of 15% in production were experienced, but even higher energy consumption reductions were realised – a cumulative 20% reduction in the base year.

The evaluation of changes in the key energy use figures were done, using 2011 as the base year for all three companies. The changes in production energy consumption were evaluated, with the view that energy consumption should remain stable, or be falling, despite production output increases, if an effective energy efficiency programme is in place. This captures the very definition of energy-efficient production – which means being able to do the same amount or more work, with less energy.

The three charts, below, show the general decreasing energy use, over time, for each of the three companies:

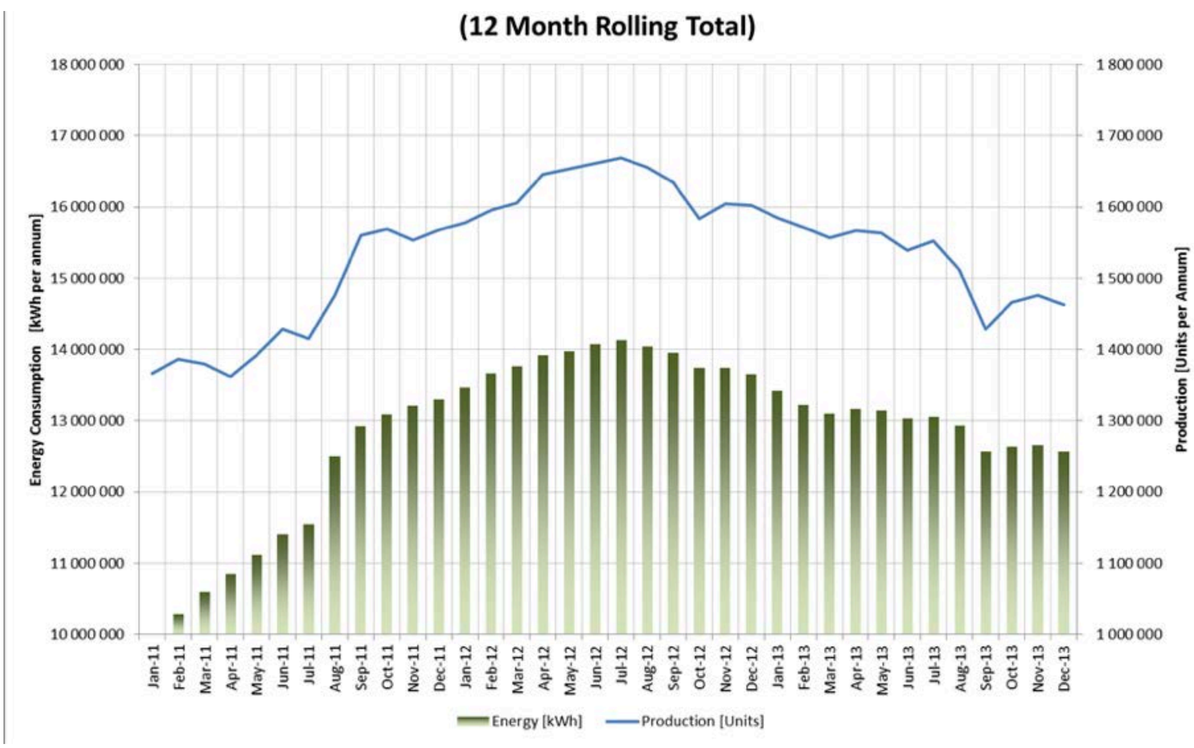

Figure 4.16: Company A production and energy trends.

Source: Own.

Figure 4.16 demonstrates the falling energy-use trends at Company A. The energy consumption drop follows the production trends, signifying production levels as a major driver of energy consumption.

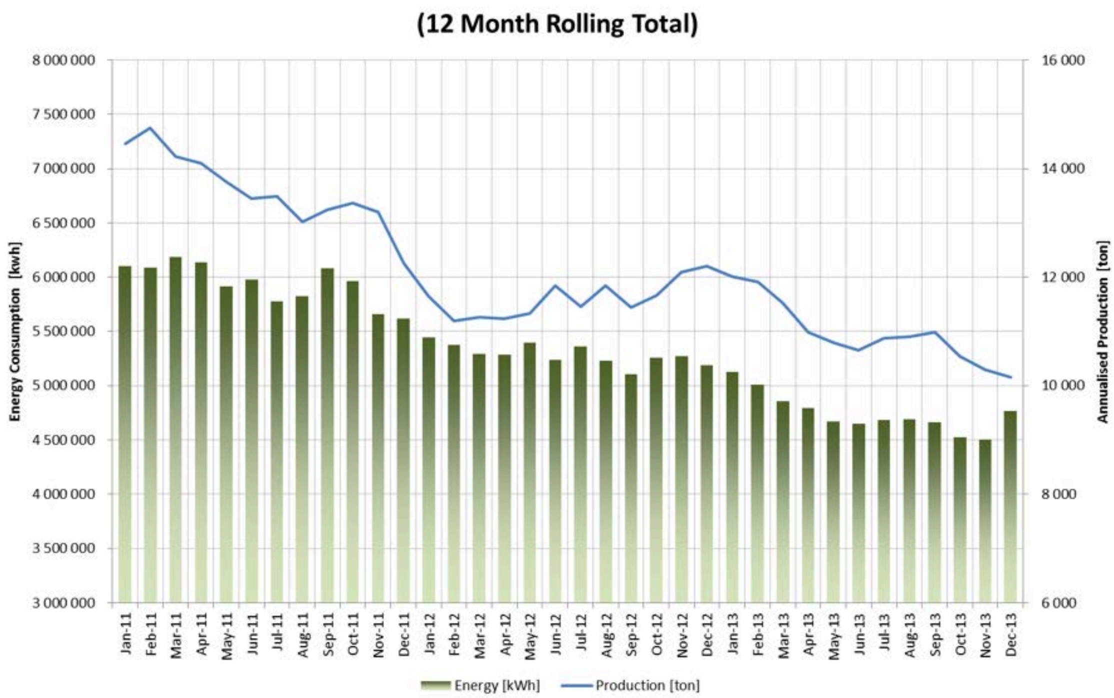

Figure 4.17: Company B production and energy trends.

Source: Own.

Figure 4.17 illustrates the reduction of energy consumption in line with production trends, resulting from implementation of energy efficiency projects.

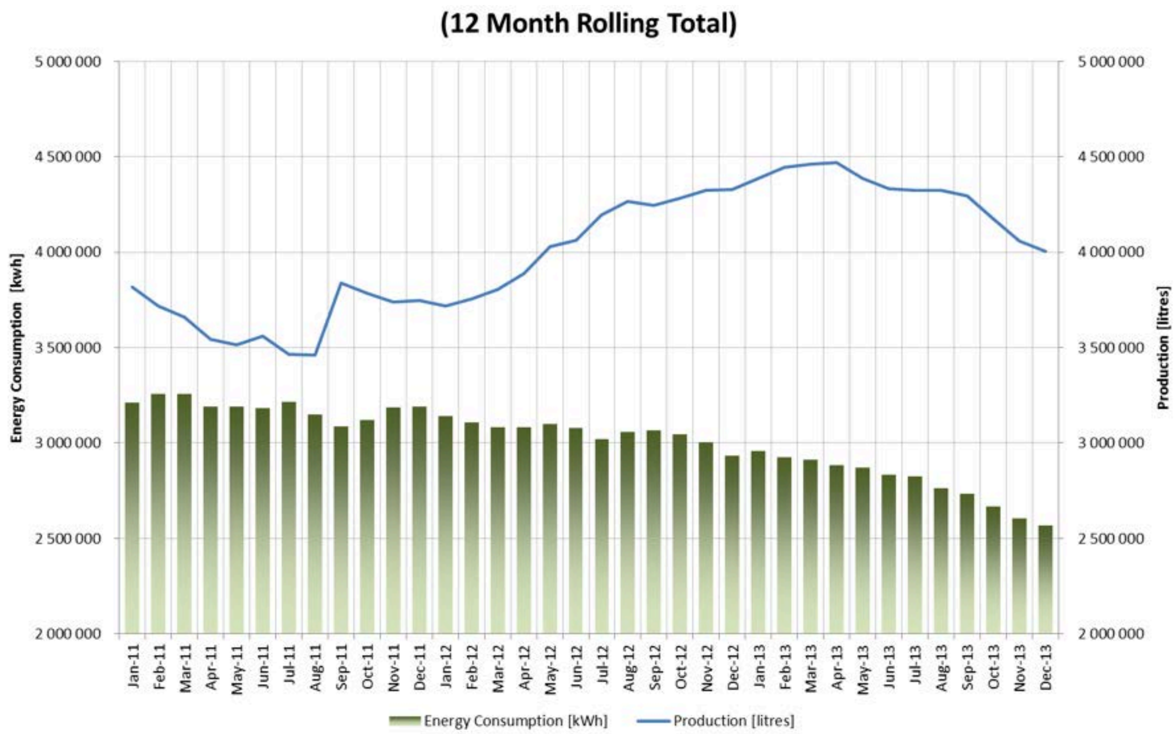

Figure 4.18: Company C production and energy trends.

Source: Own.

Figure 4.18 shows continuously decreasing energy consumption, despite increasing production, at Company C, demonstrating the impact of the implementation of energy efficiency projects in energy use.

4.4.3 Energy intensity changes

The energy intensity of a facility measures the amount of energy used per unit of productive output. The energy intensity is an indicator that can be used to benchmark a company against similar companies in the same industry. This indicator can either be calculated as a value expressing the facility's total energy use – that is, production process energy intensity and the baseload, or it can be calculated as a specific process energy intensity. The process-specific energy intensity is read from the facility's energy consumption model as the gradient of the linear regression line. The energy model, however, needs to have a high coefficient of regression, for it to be reliably used.

In the case of the evaluated entities, the original energy models had rather poor energy models, with coefficients of linear regression that were less than 50%, and so the total facility consumption, including the baseload, was used to calculate the energy intensities, and determine if there were any changes between the pre- and post-implementation periods. The shortcoming of using the overall consumption for this indicator, is that any reductions in production with a high baseload, results in increases in energy intensity levels.

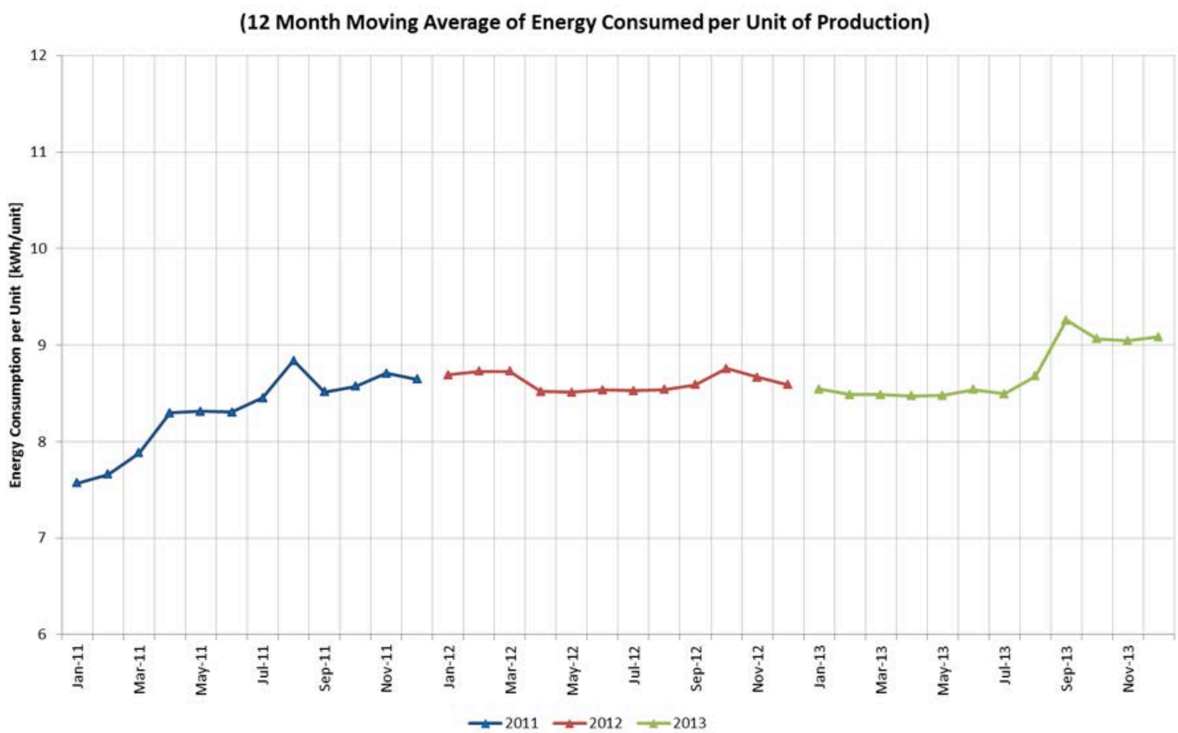

Figure 4.19: Company A energy intensity trend.

Source: Own.

Figure 4.19 shows the relatively flat energy intensity trends for Company A, which then see a step increase from September 2013. This step increase in energy intensity is due to the commissioning of new higher energy consuming equipment required to meet quality standards.

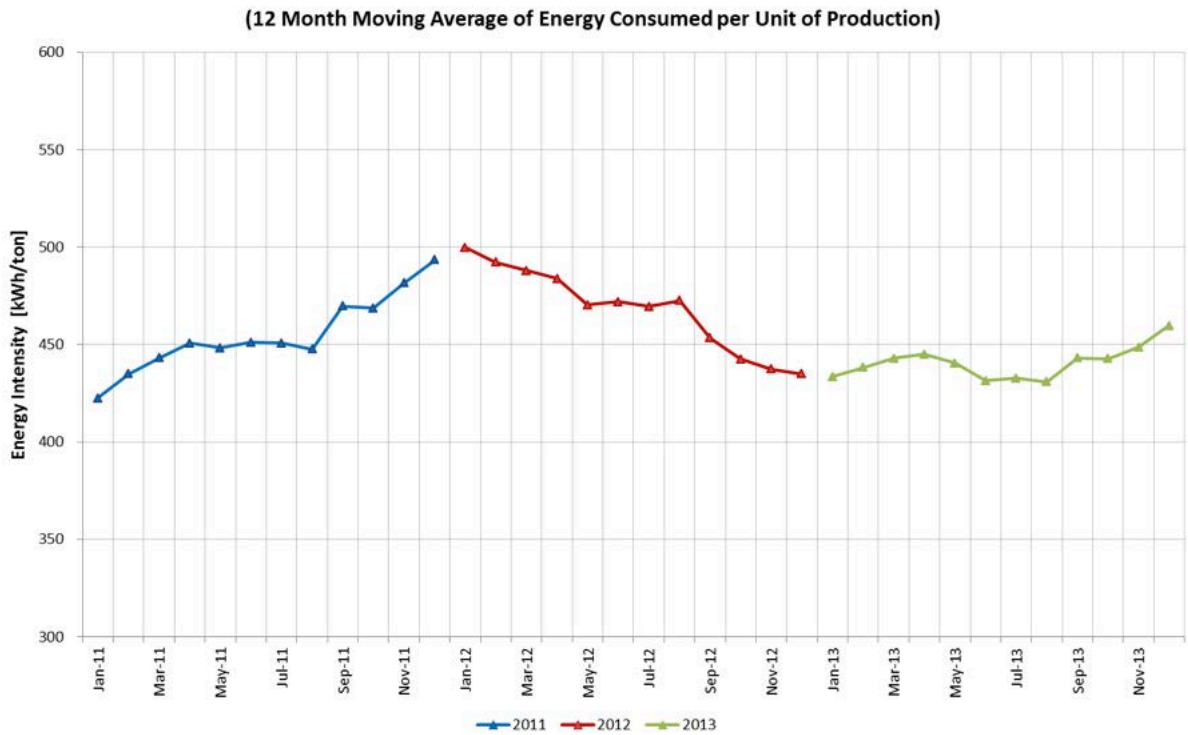

Figure 4.20: Company B energy intensity trend.
Source: Own.

Figure 4.20 shows falling energy intensity for Company B, which flattens out in 2013, and then starts to increase from August 2013. These increases in energy intensity reflect the effect of high baseloads on decreasing production levels. The energy intensity improvements obtained from implementing more energy efficient production processes, can only be identified by separating the baseload effects from the process-related energy use.

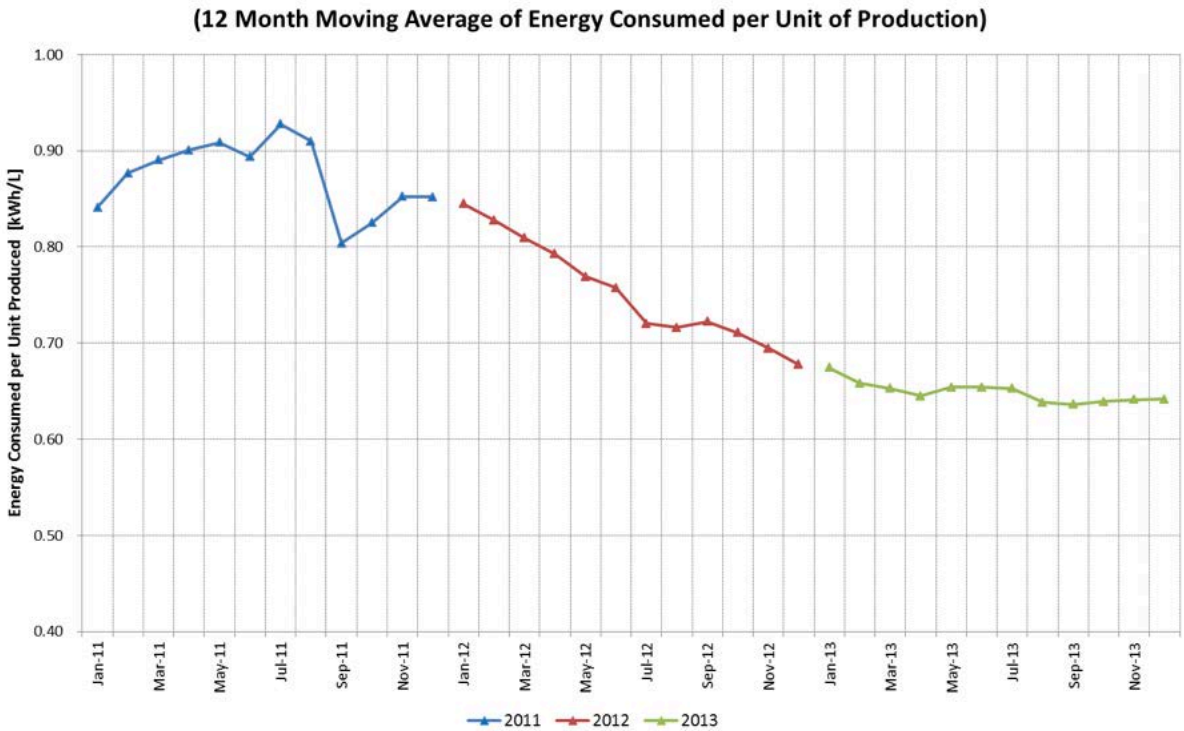

Figure 4.21: Company C Energy intensity trend.

Source: Own.

Figure 4.21 shows the decreasing energy intensities at Company C, which flatten out in 2013, and are maintained at these levels for the rest of the assessed period.

Figure 4.19 to 4.21 show the energy intensity trends for the three companies before and after the energy efficiency interventions' implementation periods.

At Company A, the energy intensity remained static at around 8.5 kWh/unit through 2012 and the first half of 2013. A sharp increase in energy intensity in September 2013 may be attributed to strike action, as well as the commissioning of new equipment at the facility.

For Company B, energy intensity rose to almost 500 kWh/ton in January 2012. There was a steady decrease to around 435 kWh/ton in August 2013. Strike action in September 2013 was a probable cause of the sharp increase. In addition, the switch from steam heating to electrical heating for the furnace rinse baths would also have contributed to the slight increase in energy intensity. The decommissioning of the copper plating line, and reduced work hours and production output, contributed to the decline in the energy intensity.

At Company C, the effects of the implementation can be clearly seen, with the steady decrease in energy intensity during 2012 and early in 2013. The plant is thus using less energy to manufacture a unit of product. As the effects of the energy savings projects were realised, the energy intensity stabilised to around 0.65 kWh/l. Further investment would be required to realise more savings and greater reductions in energy intensity.

The various trends in energy intensity were affected by the difference in both implemented projects, and structural and capacity changes, with very different results for all three companies. These results can therefore not conclusively or exclusively attribute the energy intensity changes to the implemented projects.

4.4.4 Improvements in the energy model

A common tool that is used to develop an assessment site's baseline, and also evaluate how closely production or productive activity is aligned with energy consumption, is the energy use model. The energy use model is developed by performing a linear regression analysis of the production levels or productive activity of a site, with its energy use. The coefficient of linear regression for the best fit line gives an indication of how well a productive activity explains variations in energy consumption. In the case of component manufacturing companies, this also gives an indication of how well processes are being controlled. An energy model with coefficients of regression greater than 0.7 is generally accepted as being reliable enough to use for energy forecasting. When the coefficient of regression is lower than 0.7, it is generally due to limited production processes and energy use alignment, or poor process control, including sometimes leaving equipment to idle when there is no production.

Table 4.37: Improvement in energy models regression coefficients.

	Company A	Company B	Company C
Initial Coefficient of Linear Regression	0.36	0.48	0.16
Post-Implementation Linear Regression	0.84	0.72	0.65

Source: Own.

Table 4.37 shows that the linear regression coefficients improved significantly for all three companies, with the biggest improvement happening at Company C, where the coefficient of linear regression jumped from a very low value of 0.16 to 0.65. This improvement indicates that all the companies started watching closely how the productive processes were consuming energy, and implementing measures to reduce non-productive energy use. Some of these measures were behavioural interventions that cannot be easily quantified in terms of direct energy and CO_2 reductions, but whose impact is noted in the alignment between energy use and production.

Initially, none of the energy use models could be reliably used to predict the expected energy consumption based on planned production, without significant error. After the energy efficiency projects were implemented by the companies, the models' reliability improved significantly, and can now be used in monitoring and targeting initiatives, as well as other performance measures required by an energy management system. The 'before' and 'after' energy models for each company are shown in the charts below.

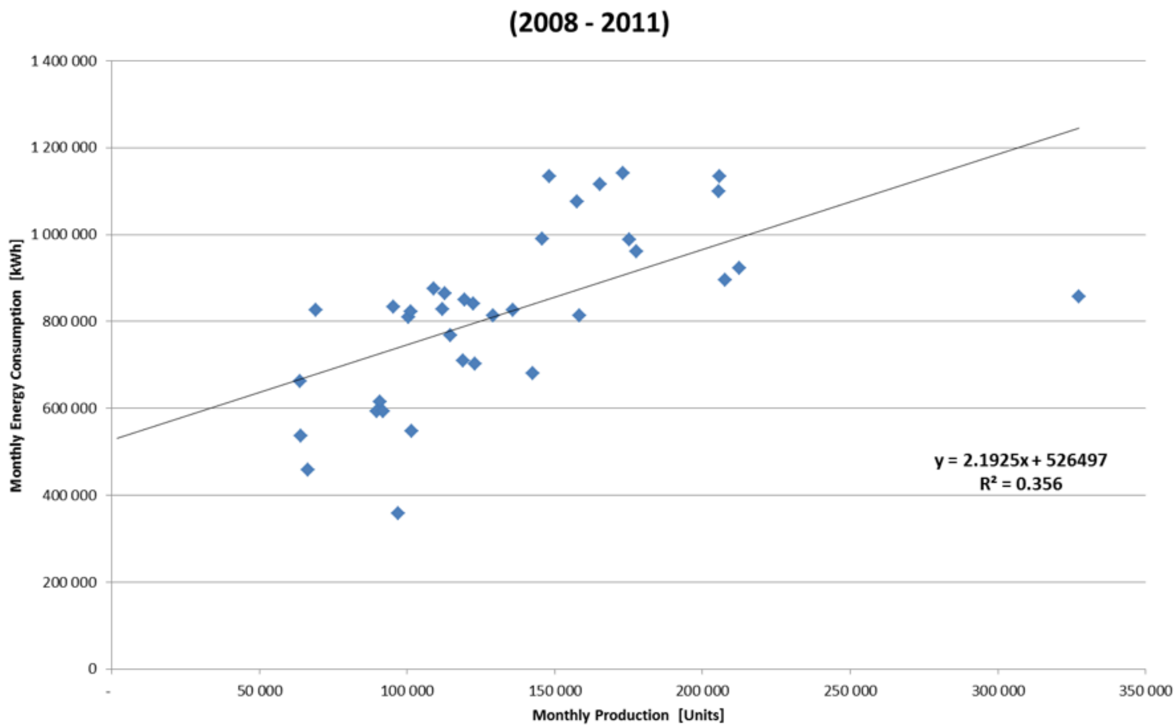

Figure 4.22: Company A original energy model.

Source: Own.

Figure 4.22 indicates the original energy use model, based on the monthly production figures of Company A. The model was developed through linear regression of a scatter plot of the monthly production and energy use data provided by the company. The equation of the best-fit line is in the form of y = mx + c, where y represents the monthly energy use, m is the specific energy use per unit of production, and c is the y-intercept, representing the facility's energy use baseload during non-production periods. The baseload is the monthly energy consumption for non-productive service loads such as compressed air, heating and ventilation or idle machinery. The coefficient of linear regression – that is, the r2-value in the chart, represents the degree of fit for the linear model. A good linear fit will have a coefficient of linear regression greater than 0.75 for monthly data, and this can be acceptably used to forecast energy use based on production levels.

In the case of Company A before implementation, the r2-value of 0.356 was low. This value means that only 35.6% of the production data could be used to explain the energy consumption of the facility. Hence, production levels could not be used to forecast energy use; neither could the model be used for analysis work such as the cumulative sum of differences tracking to monitor the impact of interventions, or other changes, in the energy use of the company.

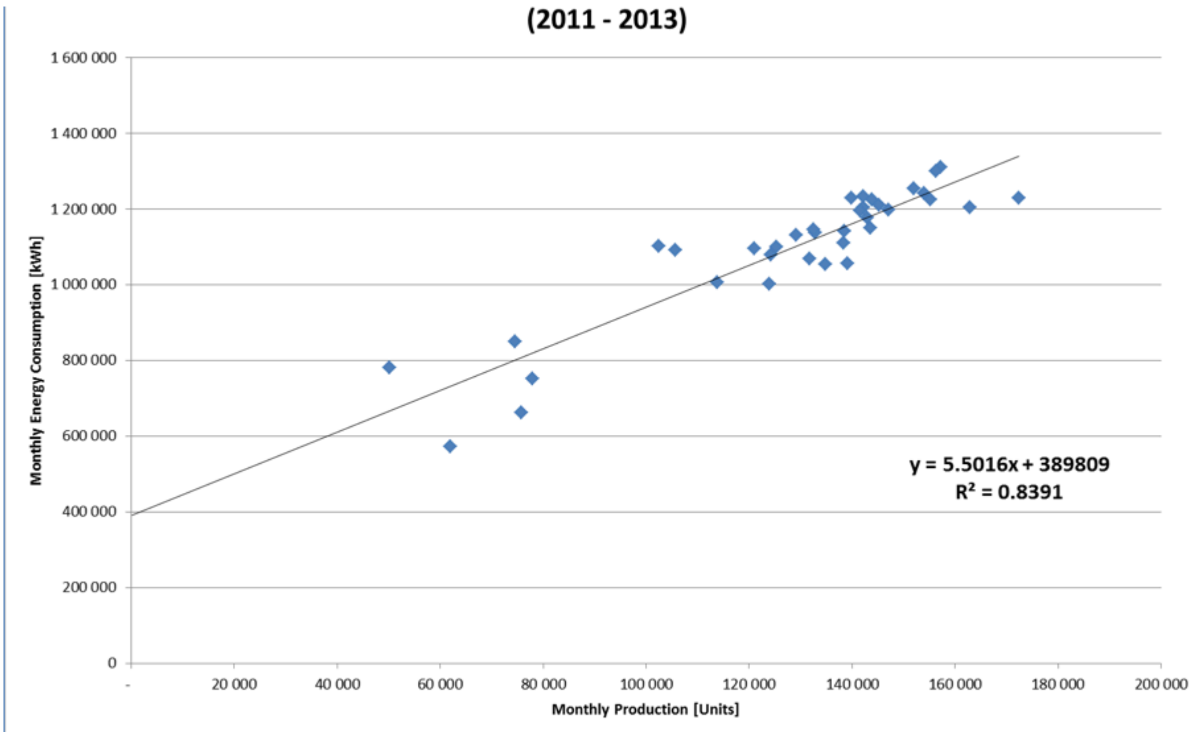

Figure 4.23: Company A post-implementation energy model.
Source: Own.

Figure 4.23 shows the post-implementation energy use model for Company A. This model shows a much better fit, with an r-squared value of 83.9%. This model could now be reliably used to predict future energy use, as well as to determine the baseload of the facility – which in this case was 389 809 kWh per month. Interventions to reduce the baseload can include minimising idling of equipment, and switching off lighting and unnecessary utilities and services during non-productive periods such as weekends.

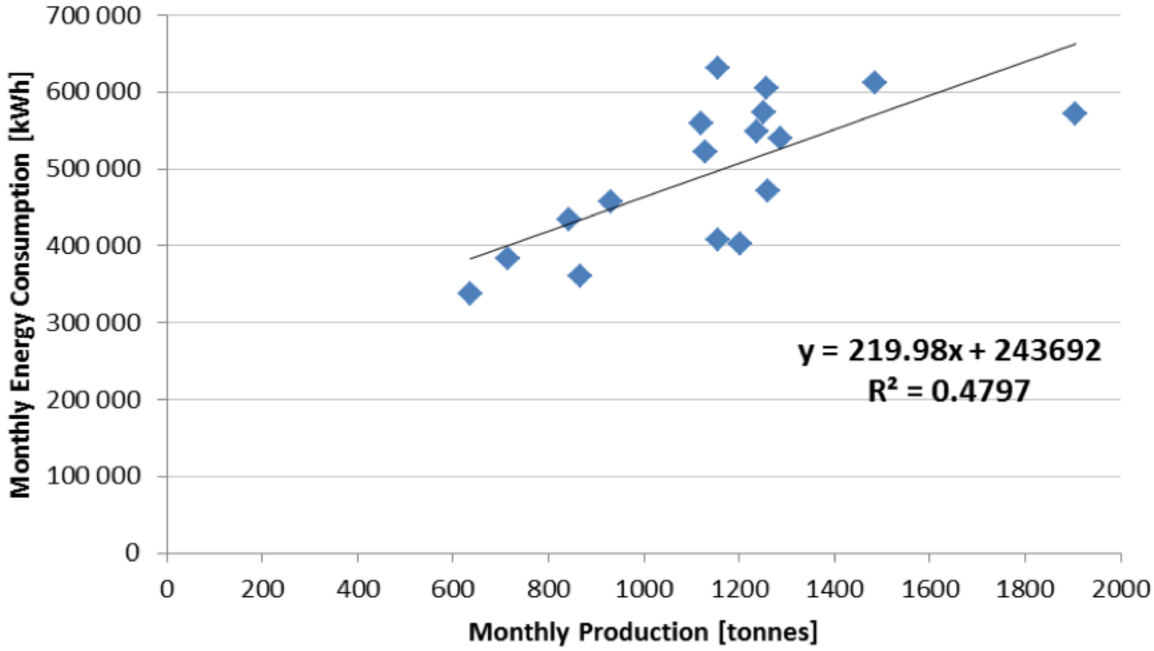

Figure 4.24: Company B Original energy model.

Source: Own.

Figure 4.24 illustrates that Company B's original model, before the implementation of energy efficiency interventions, was also low, with an r-squared value of 48%. Hence, only 48% of energy consumption could be explained by the company's production levels, and the baseload and the specific energy use could not be reliably estimated from this energy use model.

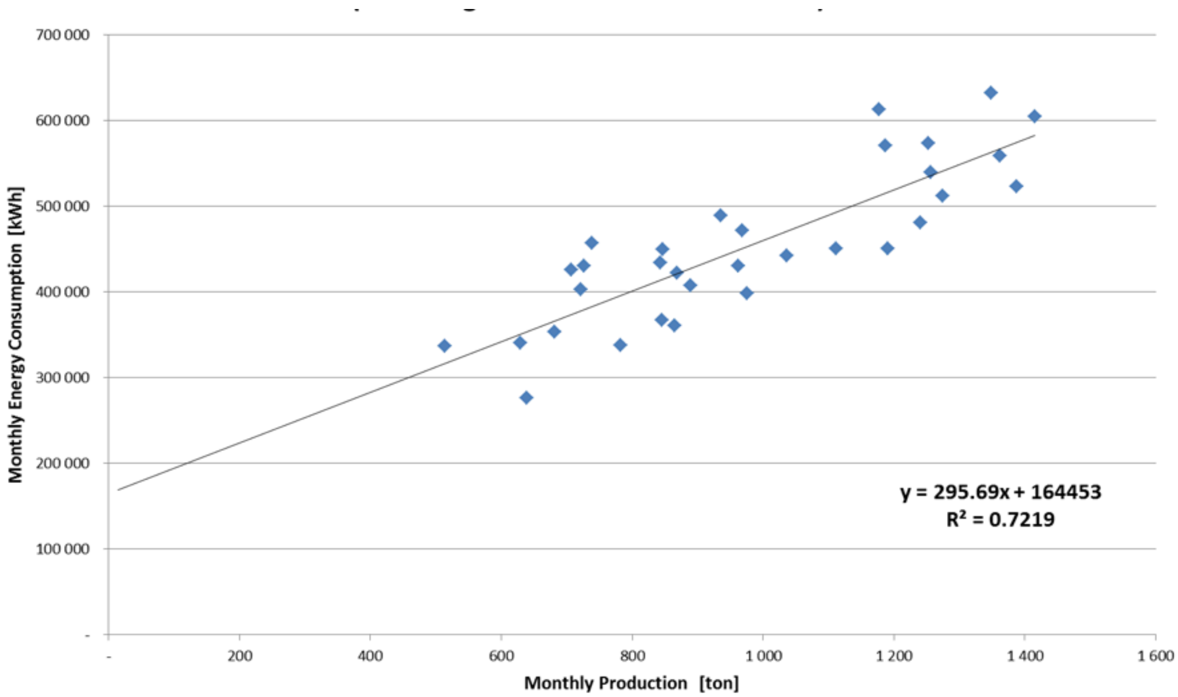

Figure 4.25: Company B post-implementation energy model.

Source: Own.

Figure 4.25 shows that after the implementation of various energy efficiency initiatives, the linear fit improved drastically to 72.2%. This means that the new model can be reliably used to predict facility energy use, and the baseload can be quantified. The baseload was 164 453 kWh/month for the evaluated period. The specific energy use was 295.7 kWh/ton. The specific energy use value can be reduced by interventions that address process optimisation issues, and the baseload, through reduction of general non-productive energy use, as discussed above.

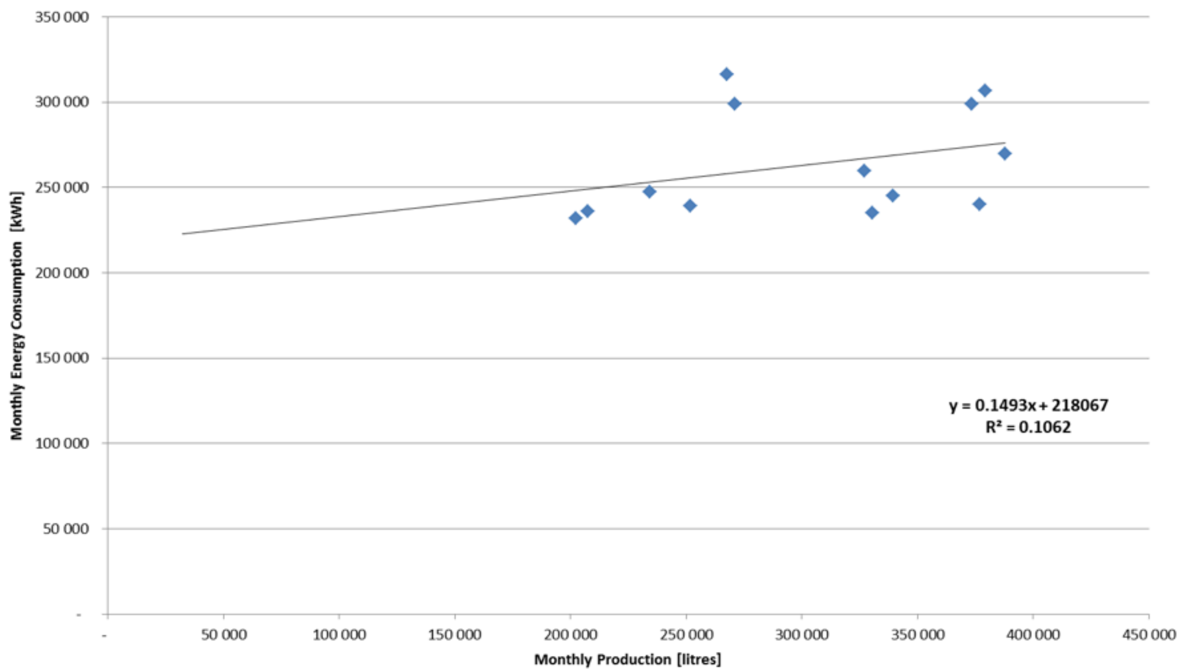

Figure 4.26: Company C original energy model.

Source: Own.

Figure 4.26 demonstrates Company C's energy model prior to any energy efficiency projects. Here it can also be seen that there was a very low fit, with an r-squared value of 10.62%. The key energy use data could thus not be reliably estimated from this model.

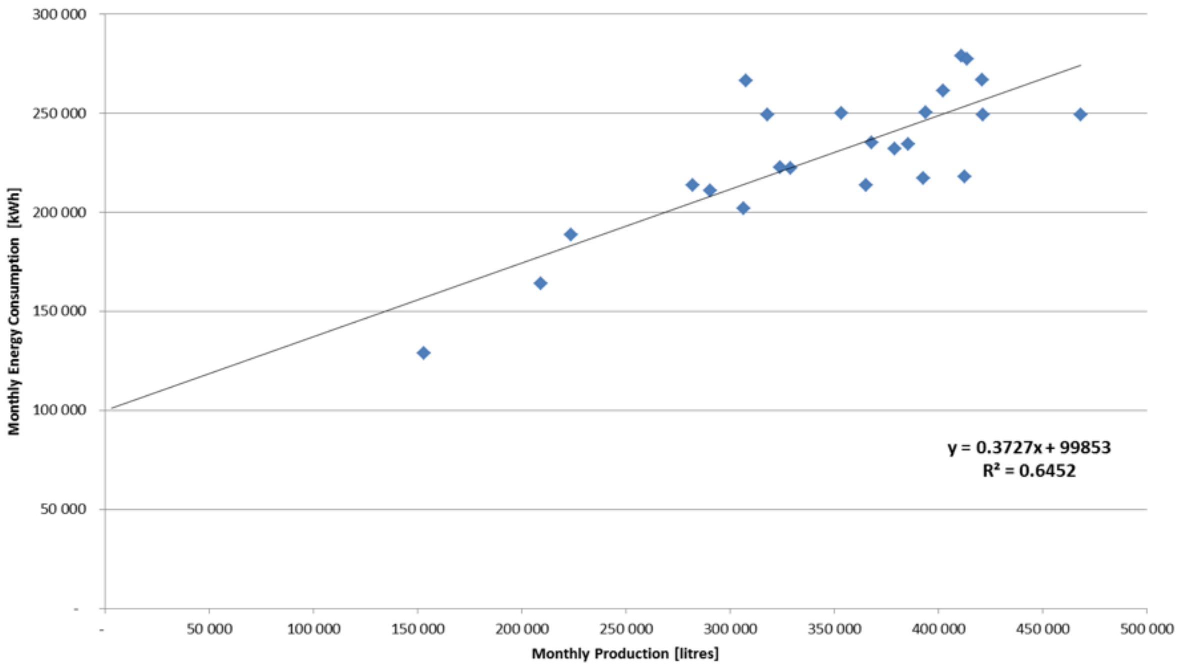

Figure 4.27: Company C post-implementation energy model.

Source: Own.

Figure 4.27 shows the post-implementation linear regression model for Company C. There was a large improvement in the r-squared value to 64.5%. Although this was still below the threshold of a 75% fit, the model can be used to estimate the key energy use figures for the facility, with some margin of error to account for the low fit. Higher resolution data could also be collected, to generate a model with a better fit.

Baseload Energy Use Improvements

The baseload energy use of a facility represents the portion of energy consumption which is used, regardless of the production output of a facility. The value is estimated by setting the y-intercept on the energy model to zero, a state which represents no productive activity in a manufacturing facility. The original energy models for the assessed companies had poor reliability for estimating the facility's baseloads, due to their poor regression coefficients.

However, the changes were deemed to be significant enough, and illustrative of the impact of implementing energy efficiency measures, to warrant including the analysis of the differences.

Table 4.38: Energy baseload changes.

	Company A	Company B	Company C
Original Baseload [kWh/month]	526497	243692	218067
Post-Implementation Baseload [kWh/month]	389809	164458	99853
Change [kWh/month]	-136688	-79234	-118214
Improvement Fraction	26%	33%	54%

Source: Own.

Table 4.38 shows the changes in the baseload for the three companies. The results for Company C were ignored, because of the extremely low initial coefficient of linear regression in the original energy model. Comparisons between Company A and Company B can be made, because they had similarly low initial regression coefficients. The average reduction in baseload was 29% across the two companies. This figure means that the companies were now paying 29% less for energy use that was not directly linked to production. Part of this reduction will have been due to intangible behavioural changes such as switching off idling equipment, improving machine utilisation, and communicating the need for plant-wide energy efficiency measures.

The decommissioning of equipment and a shortened production cycle at Company B will also have resulted in baseload reductions. At Company A, there were additions of production equipment, but the baseload came down nonetheless, and this is attributed to improved production-related energy management.

4.4.5 Environmental impact – CO_2 reductions

The environmental impact of the energy efficiency projects was measured by converting the reduction in energy consumption levels to equivalent carbon dioxide (CO_2) generation at a coal-fired power station. A conversion factor of 0.95 kg of CO_2 per kWh of energy consumption was used. An average 8% reduction in the CO_2 footprint was experienced by the companies, due to the implemented projects. The true impact of these projects was affected by the industry challenges that led to company output reductions, and changes in the originally assessed production equipment. Despite these changes, all the companies experienced a reduction in their carbon footprint, due to the implementation of energy efficiency projects.

The quantitative research findings outline that roughly 50% of the identified energy efficiency opportunities are implemented by assessed companied within the first year. Projects implemented include automated compressors, changing hot water geyser settings, installation of power factor correction and tariff structure change.

4.5 Conclusion

This chapter presented a discussion of results from the data analysis, data presentation and data interpretation. The validity and reliability of the study was tested. Qualitative and quantitative research results were presented separately. In the qualitative results, the questionnaire answers were interpreted to determine the perceptions of operational staff and company management on the implementation of energy efficiency projects. Energy assessment data analysis presented quantitative results of the type of energy projects implemented, energy consumption, and CO_2 reductions, due to the implemented projects, energy intensity changes, improvements in the energy model, and environmental impact due to CO_2 reductions.

The final chapter, Chapter 5, will be a discussion relating to the results presented in Chapter 4. Conclusions will be derived from the data analyis, and recommendations will be given.

Chapter 5

Conclusion and Recommendations

5.1 Introduction

The objective of this chapter is to present the conclusions and recommendations for the research study, in line with the aim of the study – which was to determine whether implementing energy efficiency projects within the automotive component manufacturing companies would reduce energy use and environmental pollution, and be of economic benefit to the manufacturing companies. After an introduction, the outcome of the hypothesis, citation analysis, limitation, future research, validation and reliability of the research will be discussed.

The research recommendations for the qualitative and quantitative studies will be presented separately. A qualitative research method was used to determine the perceptions of the company management and operational staff on the implementation of energy efficiency projects in the three automotive component manufacturing companies. A quantitative research method was used to determine the benefits of implementing energy efficiency projects to energy use.

The conclusions of the study discuss the need for future research.

5.2 Hypotheses

A conclusion can be drawn on all three hypotheses, from the results of the study research:

Hypothesis 1 is rejected, because evidence shows that there are definite effects of implementing energy efficiency projects.

Hypothesis 3 is rejected, due to benefits attained through the implementation of energy efficiency projects.

Hypothesis 2 is accepted, because of the benefits realised when the automotive component manufacturing industry implements energy efficiency projects.

The three companies were able to manage operational energy use. As a result, energy forecasting, and reduction of annual energy costs, was accomplished. In addition, all three automotive companies realised a reduction in their carbon footprint, due to the implementation of energy efficiency projects. An average 8% reduction in CO_2 footprint was experienced by all three companies, due to the implemented projects ultimately achieving the benefit of reducing environmental pollution.

Energy efficiency projects implemented by the three automotive component manufacturing companies to achieve these benefits, are listed as follows:

- Installation of whirlybirds on main factory roof
- Automated compressor on/off
- Changed hot-water geyser settings
- Implemented daylight harvesting
- Installed VSD-controlled compressor
- Installed power factor correction
- Installed a new energy efficient chiller plant
- Implemented tariff structure changes
- Upgraded boiler insulation
- Repaired compressed air leaks
- Automated cooling tower controls

- Installed energy efficient lighting
- Reduced furnace start-up time from 24 hours to 8 hours
- Installed lids on heated process tanks to reduce evaporative heat loss
- Reduced compressed air pressure drops, and reset compressor pressure to 6.4 bar
- Use of an electric blower for agitating the effluent mixing tank
- Use of an electric blower for cooling wire at MF2 scale breaker, instead of compressed air

It can now be said that the perceptions of the management and the operational staff on energy efficiency issues, differed in some parts. Noticeably, there is a need to promote awareness of energy efficiency. Through planned training and decisive communication, this can be achieved. To ensure sustainability, energy efficiency needs to be part of all employees' job descriptions.

Interestingly, managers and operational staff both agreed that energy efficiency projects are not a waste of time or money, thus believing that the company can benefit from the projects. Subsequently, application of energy efficiency practices were extended to the staff households, in order to gain some cost benefits through lower electricity house bills.

The success of any initiative within an organisation is greatly dependent on the involvement of staff. The results show that not all the managers within these three automotive component manufacturing companies were involved in the implementation of the energy efficiency projects. Operational staff, only half the respondents were involved in the implementation of the projects.

5.3 Citation Analysis

Interestingly, the initial citation analysis is confirmed by the research study; therefore, the outcome of the research was surprisingly similar to the citation metrics.

The focus on the citation analysis was worldwide, while the research study was focused on three automotive component companies in Nelson Mandela Bay. These focal areas, both worldwide and the three automotive component manufacturing companies, were on two totally different scales. It can therefore be agreed that international energy efficiency is the trend, and the study now confirms it locally, even though there is still work that needs to be done in the domain of energy efficiency.

Internationally, one can easily find examples of energy efficiency project results for the automotive industry. These examples were supported and guided by energy legislation and international agreements. In South Africa, one can refer to legislation, policies and initiatives; however, this could not be translated into specific implementation examples or showcases for the South African automotive industry.

5.4 Limitations

As stated in Chapter 1, section 1.4.2, the limitations had an effect in some parts of the research study. The industry was short of specifics about production costs. There can be little doubt, based on the study, that significant savings can be realised when energy efficiency projects are implemented. In general, it can be said that to improve the effectiveness of the companies, training staff in energy efficiency must be a priority.

Due to the annual automotive industrial action, entry to the three company sites was halted for that period of time. As a result, the number of participants answering the questionnaire was reduced to those who had the time and were comfortable in responding to the questionnaire. Operational aspects became the focal point, once the industrial actions came to an end. One of the companies was going through a change management process, so no questionnaires were received from the managers; only operational staff participated. Notwithstanding all the above, the researcher concludes that it is representative of the dynamics of the automotive industry in South Africa.

5.5 Validity and Reliability

As discussed in section 4.1.2, research is considered reliable when the same results are obtained when repeated analysis of the questionnaire is done. It was also discovered that after the energy efficiency projects were implemented by the three companies, the models' reliability improved significantly, and could be used in future for monitoring and targeting initiatives, as well as other performance measures required by an energy management system.

As stated in section 4.1.3, the testing and measuring of the questionnaire was extensive. Factor analysis was conducted, showing high positive loading of six factors. These factors were generated using variables such as Energy Projects, Energy Efficiency Understanding and Training Energy Efficiency, which formed part of the construction of the questionnaire. Through positive results of the analysis, it can therefore be deduced that the study was valid.

5.6 Recommendations

5.6.1 Recommendations based on the qualitative analysis

Energy efficiency projects were implemented within three automotive component manufacturing companies. For these companies to be able to note the effectiveness of these projects, staff on management level and operational staff require a clear understanding of the concept of 'energy efficiency'. It was imperative for each staff member to be made aware of these projects, in order for them to understand their own roles and responsibilities towards this energy efficiency initiative. The purpose of energy efficiency projects within companies is to save energy and reduce the impact on the natural environment.

Before companies are able to achieve greater savings on energy, their staff members would need to be educated and trained to understand the benefits of saving energy. Where automotive component manufacturing companies have employees who do not understand what energy efficiency is, training and awareness programmes need to be introduced, in order to educate the employees, so that they are enabled to put their energy savings knowledge into action.

Employees need to know whether energy efficiency is part of their job responsibilities. In instances where employees perceive the energy efficiency projects and campaigns to be a waste of time, companies need to educate their employees in the benefits of such projects.

Companies need to go back to those employees who found the training relating to energy efficiency and awareness campaigns to be poor, to understand what was missing from the training and the campaigns. This is in order for them to compile comprehensive training which will cover all the aspects of the projects, so that employees can become empowered by the training and awareness.

Automotive component manufacturing companies ought to ensure that they adequately communicate their energy targets and savings achieved, so that each and every employee can be informed. These companies need to come up with incentive schemes, in order to recognise and reward individuals who are making an effort to save energy – especially those who do not have energy efficiency as part of their job responsibilities. This will motivate employees, and benefit the three companies in achieving energy savings and environmental targets.

5.6.2 Recommendations based on the quantitative analysis

These recommendations are centred on switching off equipment when not required. The extent of implementation of energy efficiency operational-type projects needs to be quantified. Projected savings will only be realised where personnel meticulously execute the work instructions relating to manual switching off of machinery and other equipment. As an alternative, the use of sensors, timers and other automated control devices should be investigated, and implemented where feasible.

It is recommended that Company A review their production costing models to accommodate all manufacturing process elements, as well as the inclusion of scrap throughout the production line. Company A is investigating the possible use of renewable technologies.

At Company B, the focus was on achieving operational stability though an increase in production volumes. Further energy savings may be achieved by the following actions:

- Reviewing its energy balance;
- Redefining energy objectives and targets in a sustained stable operating environment;
- Optimising the compressed air system; and
- Modification of electrical reticulation at the plant, to eliminate losses in redundant equipment, transformers and cables.

Company C has committed itself to the principles of energy efficiency. As part of its drive towards efficiency, the following projects have been identified for possible implementation:

- Developing in-house expertise for the implementation of energy management systems;
- Possible implementation of ISO 50 001;
- Optimisation of specifically identified pump systems;
- Further lighting-savings projects;
- Possible installation of renewable energy technology;
- Installation of technology to reduce wastewater disposal costs; and
- Supply chain management optimisation.

More improvements to consider for factory supply include that a review of each process or energy system would need to be completed, based on equipment size and rating.

It is also recommended that immediate future energy-saving projects be focused around the following items:

- Continued efficient lighting replacement programme;
- Installation of occupancy sensors and timers for equipment in identified areas;
- Heat recovery of BMC oven;

- Operational discipline in manual switching of equipment based on requirements;
- Optimisation of identified pump systems; and
- Resizing of identified motors.

Suggested possible energy saving projects include the following:

- Continue lighting retrofit for areas not included in first phase;
- Install motion sensors for lighting areas not often occupied: this would include warehousing, finished goods stores, raw material stores, and workshops;
- Analyse pumping systems for opportunities in terms of pump sizing, usage during lunch breaks, and possible automated operational control;
- Analyse large motors for correct sizing and load characteristics. This would include determining whether a VSD would be suited to the application;
- Analyse conveyor systems for usage times, possible automated control, and energy efficient motors; and
- Determine operating conditions for laboratories and other environmentally controlled areas, and ensure that the control systems for these are appropriate, and correctly sized and operated. Opportunities for passive control (for example, improved insulation and double-glazed windows) of these areas should also be investigated.

5.6.3 Research conclusion and future research

This study demonstrates that there is a pressing need for further research to be undertaken, to improve efficiency for energy within the automotive manufacturing industry in South Africa.

Overall, there can be little doubt, as demonstrated by this case study, that energy efficiency projects hold great potential to benefit the automotive manufacturing industry. The objectives of the research were achieved by using a mixed mode methodology. The purpose of the study was (a) to identify implemented energy efficiency projects, (b) to determine whether there are benefits for the companies when energy efficiency projects are implemented, and (c) to investigate the perceptions of company management and operational staff on implementation of energy efficiency projects.

The findings indicated that 80% of the managers agreed that energy efficiency is not part of their job responsibilities, while 80% of operational staff said that energy efficiency does form part of their day-to-day activities. Over 50% of the identified energy efficiency projects were implemented by the automotive component manufacturers. As a result, significant changes in energy saving were achieved and companies paying 29% less for energy use.

In conclusion, automotive component manufacturers need to determine a site energy baseline annually, and also evaluate how closely production activities aligned with energy consumption is the energy use model. Behavioural interventions cannot be easily quantified and have a direct impact on energy use and production; automotive component manufacturing companies must therefore put interventions in place. Staff on management level, and operational staff, need to have a clear understanding of the concept of energy efficiency. Each staff member should be made aware of their role and responsibilities in working towards these energy efficiency initiatives.

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ANNEXURES

Annexure A: Questionnaire

<u>Questionnaire for energy efficiency implementation at the automotive component manufacturer</u>

Thank you for joining us. Please understand this interview will be done in confident thus names of participants will not be mentioned.

This exercise is conducted to gain understanding of the representatives' concerns and appreciation of the energy efficiency projects implementation occurring within their working environment.

Please note that:

- Completion of the questionnaire will not be longer than 20 minutes.
- Participants are not obligated to complete the questionnaire, and at any time could withdraw from taking part;
- Participants are only allowed to sign the consent form when satisfied with the explanation; and
- To ensure confidentiality, the questionnaires will be stored in a locked cabinet, and research data was password protected.

For any queries please contact Thembi Kodisang at (012)841 3571

1	I understand what energy efficiency and cleaner production is.	Strongly Agree	Partly Agree	Not Sure	Partly Disagree	Strongly Disagree
2	Where do you put your energy knowledge into action? A. I routinely try to save energy both at home and at work. B. I focus my efforts on saving energy at home. C. I focus my efforts on saving energy at work. D. I don't usually think about trying to save energy.	A	B	C	D	
3	Energy efficiency is not part of my job responsibilities.	Strongly Agree	Partly Agree	Not Sure	Partly Disagree	Strongly Disagree
4	A dedicated energy team must be appointed to focus on energy, so I can focus on my daily work.	Strongly Agree	Partly Agree	Not Sure	Partly Disagree	Strongly Disagree
5	The energy efficiency projects at our workplace are a waste of time and money.	Strongly Agree	Partly Agree	Not Sure	Partly Disagree	Strongly Disagree
6	I am aware of the energy targets of the company.	Strongly Agree	Partly Agree	Not Sure	Partly Disagree	Strongly Disagree
7	Have you been involved in implementation of energy efficiency projects?	Yes		No		
8	Your role in the project was clearly explained and demonstrated to you.	Strongly Agree	Partly Agree	Not Sure	Partly Disagree	Strongly Disagree
9	Your role in terms of energy savings has been written into your job description.	Yes		No		
10	You have been given targets for your specific work relating to energy savings.	Yes		No		
11	The level of training provided to you, relating to energy efficiency, was…	Very Good	Good	Not Sure	Poor	Very Poor
12	The energy efficiency awareness campaigns at the workplace are ….	Very Good	Good	Not Sure	Poor	Very Poor
13	The communication of energy targets and savings achieved at the workplace is …	Very Good	Good	Not Sure	Poor	Very Poor
14	Individuals are recognised for their efforts in energy saving.	Strongly Agree	Partly Agree	Not Sure	Partly Disagree	Strongly Disagree

15	Which tasks form part of your daily routine, that contribute towards energy saving?	____ ____ ____
16	Can you think of two instances where the company is wasting energy?	1____ 2____
17	Do you have any energy saving schemes at home? List the three main ones that you think saves you the most.	1____ 2____ 3____

Annexure B: Consent form

Consent form

Research Title A CASE STUDY TO ASSESS THE BENEFITS OF IMPLEMENTING ENERGY EFFICIENCY PROJECTS AS PERCEIVED BY THREE AUTOMOTIVE COMPONENT MANUFACTURERS IN THE NELSON MANDELA BAY MUNICIPALITY

Purpose of study

This exercise is conducted to gain understanding of the representatives' concerns and appreciation of the energy efficiency projects implementation occurring within their working environment.
Location ________________________ Date: ____/ _____/ 2014

Research Process

1. This survey will be done using a questionnaire and not discussion, to protect and allow the participant to express their opinions freely.
2. The process will not be longer than 20 minutes, to ensure production time is not affected negatively.
3. To ensure anonymity participants are not required state their name.

Confidentiality

Your opinions and rating on the questionnaire are view as confidential; only the research team will access the information.

Withdrawal Clause
This process is voluntarily, thus participants may stop at anytime and not complete the questionnaire.

Consent

I, the undersigned, ………………………………………………… (Designation) have read the above information relating to the project and have also heard the verbal version, and declare that I understand it. I have been afforded the opportunity to discuss relevant aspects of the project with the project leader, and hereby declare that I agree voluntarily to participate in the project.

I indemnify the university and any employee or student of the university against any liability that I may incur during the course of the project.

I further undertake to make no claim against the university in respect of damages to my person or reputation that may be incurred as a result of the project/trial or through the fault of other participants, unless resulting from negligence on the part of the university, its employees or students.

I have received and signed copy of the consent form.

Signature of participant: ....

Signed at ……………………………… on ………………………………

Annexure C: Research Permission letter

NCPC
NATIONAL CLEANER PRODUCTION CENTRE
SOUTH AFRICA

Date: 17 May 2013

Enquiries:
Mr Gerswynn Mckuur
Tel: (012) 841 2403
Fax: (012) 841 5039
E-mail: gmckuur@csir.co.za

Letter of Permission to use Business-related Data in Master's Thesis

To whom it may concern

The National Cleaner Production Centre of South Africa (NCPC-SA) is the key industrial sustainability programme of the Department of Trade and Industry (the dti), hosted at the CSIR. Its mandate is to enable South African industry to increase its competitiveness and sustainability through more resource efficient and cleaner production.

In my capacity as Senior Projects Manager and on behalf of the National Cleaner Production Centre of South Africa, I hereby wish to confirm that permission has been granted to VTMS Kodisang to use certain confidential business-related information in relation to her Master's Degree Research Proposal and thesis.

In its engagements with manufacturing companies, the NCPC-SA through the CSIR enters into a Memorandum of Agreement (MOA) with the participating companies. The MOA allows the NCPC-SA/CSIR access to the site and its data and ensures the protection of proprietary information but allows for the anonymous use of data obtained during the aforementioned engagement.

In this case, the NCPC-SA/CSIR has authorized that VTMS Kodisang is allowed to use such anonymised data for her Master's Degree Research Proposal and thesis. The terms of this authorisation are set out in the attached document "*Confidentiality Undertaking Memorandum of Confidentiality*" and agreed to by both parties.

The use of confidential information in this case, pertains to three automotive component manufacturers based in Port Elizabeth (Nelson Mandela Bay Metropolitan).

Yours truly,
Gerswynn McKuur
Senior Project Manager
National Cleaner Production Centre - South Africa

National Cleaner Production Centre of South Africa
Meiring Naude Road, Brummeria
P.O.Box 395, Pretoria, 0001
Web site: http:// www.ncpc.co.za
Executive Management Committee members: The dti,CSIR

Annexure D: Factor Analysis

As part of the research methodology in Chapter 3, factor analysis was undertaken for data analysis of the qualitative research.

Factor analysis is a useful tool for investigating variable relationships for complex concepts such as socioeconomic status, dietary patterns, or psychological scales. It allows the researcher to investigate concepts that are not easily measured directly by collapsing a large number of variables into few interpretable underlying factors. (Rahn, 2012).