Examining Energy Efficiency Potential in South African Manufacturing Facilities: The Case of AECI's Green Gauge Energy Efficiency Programme

by

Tredeshnee Naidu

Thesis presented in partial fulfilment of the requirements for the degree of Master of Philosophy in Environmental Management in the Faculty of Economic and Management Sciences at Stellenbosch University

Supervisor:

Professor Josephine Kaviti Musango

March 2020

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: March 2020

Abstract

Globally energy efficiency plays a vital role in reducing energy demand and consumption, limiting global warming by reducing carbon dioxide (CO_2) emissions and improving economic competitiveness. As the industrial sector consumes more energy than any other sector there is vast opportunity to derive benefit from implementing energy efficiency programmes. Industries have been implementing a number of energy efficiency programmes globally, but there is still a large percentage of opportunities that remain unimplemented with the potential for energy savings ranging from 8 to 61% across developed and developing countries.

This study focuses on evaluating the effectiveness of implementing energy efficiency projects in industries, using the energy efficiency component of AECI's Green Gauge programme as a case study. The first part of the literature review focused on assessing the key drivers and barriers towards implementing energy efficiency measures in industry globally and locally, and the second part examined the extent of energy efficiency and its components used in the manufacturing sector. A synthesis of the results of AECI's Green Gauge programme is then presented by connecting the key outcomes from analysis of the quantitative and qualitative data and then connecting the literature review with practice. The energy efficiency component of AECI's Green Gauge programme was overall beneficial to the 16 manufacturing facilities that implemented the programme realising approximately 11% of the total potential energy savings. One of the key outcomes was that the majority of the energy efficiency measures implemented in the Green Gauge programme were low or no capital investment and low payback opportunities. Extrapolating the energy savings from the low or no capital investment and low payback projects from AECI's Green Gauge programme to the South African Industrial sector, it was estimated that energy savings of approximately 10% of South Africa's electricity consumption can be realised.

The key findings and insights were used to develop a model to enable companies to practically roll out an energy efficiency programme taking into account key insights emerging from the results.

Opsomming

Energiedoeltreffendheid speel wêreldwyd 'n belangrike rol in die vermindering van die vraag en verbruik na energie, asook wat betref die beperking van aardverwarming deur die vermindering van koolstofdioksied-uitlatings (CO2) en die verbetering van ekonomiese mededingendheid. Aangesien die nywerheidsektor meer energie verbruik as enige ander sektor, is daar eindelose geleentheid om voordeel te trek uit die implementering van energie-doeltreffendheidsprogramme. Nywerhede implementeer wêreldwyd 'n aantal energie-doeltreffendheidsprogramme, maar daar is steeds 'n groot persentasie geleenthede met die potensiaal vir energiebesparing – dit wissel tussen 8 en 61% in ontwikkelde en ontwikkelende lande – wat nie toegepas word nie.

Hierdie studie fokus op die evaluering van die doeltreffendheid van die implementering van energie-effektiwiteitsprojekte in nywerhede, en gebruik die energie-doeltreffendheidskomponent van AECI se Green Gauge-program as gevallestudie. Die eerste deel van die literatuuroorsig fokus op die beoordeling van die belangrikste dryfvere en hindernisse in die uitvoering van energie-doeltreffendheidsmaatreëls in die nywerheid wêreldwyd en plaaslik, en in die tweede deel word die omvang van energie-doeltreffendheid en die komponente, wat in die vervaardigingsektor gebruik word, ondersoek. Daarna word 'n sintese van die resultate van die Green Gauge-program van AECI aangebied deur die belangrikste uitkomste uit die ontleding van die kwantitatiewe en kwalitatiewe data te verbind en die literatuuroorsig dan met die praktyk te verbind. Die energie-doeltreffendheidskomponent van AECI se Green Gauge-program was oor die algemeen voordelig vir die 16 vervaardigingsfasiliteite wat die program geïmplementeer het, en het ongeveer 11% van die totale potensiële energiebesparing bereik. Een van die belangrikste uitkomste was dat die meerderheid van die energie-doeltreffendheidsmaatreëls, wat in die Green Gauge-program geïmplementeer is, min was met geen kapitaalinvestering en lae terugbetalingsgeleenthede. Met die ekstrapolering van die energiebesparing van die lae, of geen kapitaalinvestering, en lae terugbetalingsprojekte van AECI se Green Gauge-

program na die Suid-Afrikaanse nywerheidsektor, word geraam dat energiebesparing van sowat 10% van Suid-Afrika se elektrisiteitsverbruik gerealiseer kan word.

Die belangrikste bevindinge en insigte is aangewend om 'n model te ontwikkel om ondernemings in staat te stel om 'n energie-doeltreffendheidsprogram prakties uit te voer met inagneming van sleutelinsigte wat uit die resultate voortspruit.

Acknowledgements

Thank you to my family for their unwavering support especially my parents, Prakashnee and Vishnu Naidu, for believing in my ability to succeed and always cooking and taking care of me when I didn't have time to do the basics. To my sister and soul mate, Eudeshi Naidu, thank you for being my emotional support and listening to my endless complaints during this process. Your love and care during this year and throughout my life has always given me the strength to overcome my obstacles and the courage to never give up. You are the wind beneath my wings and I will be forever grateful for your unconditional love and support.

To my incredible friend, Morgan Ramsamy, for always being so patient with my complaints, a shoulder to cry on many, many times during this year and a source of emotional support throughout this journey. Thank you for your faith and belief in me and your endless encouragement and positivity throughout this process. In addition your gorgeous babies, Kamran and Shreya, are always a source of absolute joy to me and will always be an integral part of my life.

To my childhood friend, Nikita Lalla, for always believing in me and taking me out to lunch or a coffee whenever I needed a break. To my friend and colleague, Alexandra O'Donoghue for your support when I needed you the most and for your constant encouragement and compassion. To my very intelligent cousin, Kamal Naidu, thank for your guidance and words of wisdom during the early stages of this process.

To my supervisor for her guidance and patience which assisted greatly in shaping my thoughts leading to achieving this milestone.

I finally want to thank my brilliant friend and colleague, Joslin Lydall, for being an incredible help towards formulating my thoughts and setting me on the right track when I didn't think it was possible. You were the light at the end of my tunnel and I am ever so grateful for your support in getting me through this journey. Thank you from the bottom of my heart.

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

CDP	Carbon Disclosure Project
CO_2	Carbon dioxide
COP 22	22^{nd} Conference of the Parties
DTI	Department of Trade and Industry
EnMS	Energy Management Standard
ESO	Energy Saving Opportunity
GJ	Gigajoule
GJ/T	Gigajoule per tonne
GHG	Greenhouse gas
IAC	Industrial Assessment Centre
IEA	International Energy Agency
IEP	Integrated Energy Plan
ITA	Italian database
ISO	International Organisation for Standardisation
kWh	Kilowatt hour
MWh	Megawatt hour
NBI	National Business Initiative
NCPC-SA	National Cleaner Production Centre of South Africa
OECD	Organisation for Economic Co-operation and Development
PJ	Petajoule
PSEE	Private Sector Energy Efficiency
SDG	Sustainable Development Goals
SME	Small Medium Enterprise
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
WEO	World Economic Outlook
ZW	Ziga watt

Chapter 1 – Introduction

1.1 Background

Energy is a critical basic need in the industrial sector globally. Energy efficiency 'is recognised globally as a critical solution to reducing energy demand and consumption, managing global carbon dioxide (CO_2) emissions and improving economic competitiveness' (Dos Santos, 2017:3). 'The global energy industry finds itself in urgent need of energy efficiency intervention, in support of preventing the earth from heating up by 4.5^{o}C by 2100' (Arnoldy, 2018:1). At the 2015 Conference of the Parties, 196 parties committed to preventing dangerous climate change by limiting global warming to well below 2 degrees Celsius by setting ambitious targets. According to the International Energy Agency (IEA) (IEA,2017) multiple pathways for energy through to 2040 are described. One of the pathways, the New Policies Scenarios (based on existing policies and announced intentions), predicts that 'global energy needs rise more slowly than in the past but still expand by 30% between today and 2040'. It is estimated that this is the equivalent of increasing the current demand by the combined current demand of China and India.

With the industrial sector consuming more energy than any other sector globally, consuming approximately 37% of the world's delivered energy (Abdelaziz et al., 2011:152), there is significant opportunity for energy efficiency initiatives. The implementation of energy efficiency programmes has become increasingly prevalent in the twenty-first century in many companies locally and globally. There are several reasons for implementation of such programmes, the most common of which are:

- The growing global perception that investors favour companies that implement green initiatives, e.g. the Carbon Disclosure Project (CDP) requiring companies to provide information on carbon and energy information which is requested by investors representing more than US$100 trillion (CDP, 2018).

- The incorporation of the six capitals in the King IV report that organisations use or are affected by of which the natural capital reflective of environmental matters is a material organisational consideration (Institute of Directors of Southern Africa; 2016:24).
- The significant increase in electricity prices in South Africa and the strain on the grid from 2008 onwards having a severe impact on high energy consuming companies forcing companies to look at reducing energy consumption. It is also worth noting that electricity costs are expected to continue increasing at levels above the Consumer Price Index (Dos Santos, 2017:3).

The key purpose of the study is to evaluate the effectiveness of the energy efficiency component of manufacturing facilities, using AECI's Green Gauge programme[12] as a case study. AECI Ltd (previously known as African Explosives and Chemical Industries, now known as AECI) is a South African-based company in the manufacturing sector and has regional and international businesses that provides products and services to customers in the mining, water treatment, plant and animal health, food and beverage, infrastructure and general industrial sectors (AECI, 2019). AECI formulated and implemented a set of mid-term environmental targets named the AECI Green Gauge programme in 2011. This resource efficiency programme served as a yardstick for the environmental activities from 2011 to 2015. The aim of the Green Gauge programme was to reduce the environmental footprint of the Group's activities beyond just environmental compliance to minimise environmental harm by setting targets to reduce the energy, water and waste footprints. This study focuses on the energy efficiency component of the Green Gauge Programme.

The approach taken in the design and implementation of the Green Gauge Programme strategy was a comprehensive one aimed at creating efficiencies whilst encouraging growth and development, sustaining service delivery and

[1] The 2015 Conference of the Parties (COP) was held in Paris, France in December 2015. It was the 21st annual session of the COP to the 1991 United Nations Framework Convention on Climate Change https://en.wikipedia.org/wiki/2015_United_Nations_Climate_Change_Conference
[2] AECI Green Gauge programme was established in 2011 and concluded in 2015

service delivery expansion, and also providing opportunities for economic growth whilst aiming to manage AECI's environmental footprint in a diligent manner.

The Green Gauge programme was concluded in 2015 with management displaying both satisfaction and criticism of the programme. During the programme there were also business challenges impacting on implementation of projects.

In undertaking the energy efficiency analysis in the AECI's Green Gauge programme, the study intends to inform the company on whether a similar programme should be implemented and employed at other manufacturing sites within the AECI Group. In addition, the study provides other companies in the manufacturing sector with recommendations, insights and a model for implementing a similar energy efficiency programme at their facilities. Several factors, both quantitative and qualitative, influence the effectiveness of the programme including the extent of implementation of energy efficiency measures and the drivers and barriers that contribute towards implementation of the programme.

1.2 Problem statement

Preliminary indications show that although AECIs Green Gauge programme identified several opportunities for reducing energy consumption, only a limited number of those opportunities have been implemented in the energy efficiency area since the start of the programme in 2011. Some reasons for lack of and reduced implementation were the large capital investments required with low payback periods, additional detailed and costly engineering studies to establish commercial viability, and lack of a defined regulatory energy efficiency landscape to justify significant capital investment.

The issue required to be investigated is whether the energy efficiency programme was beneficial to AECI to inform the company whether it should invest in a similar energy efficiency programme in its efforts to reduce its environmental impact further and reduce energy consumption and costs. No quantitative and qualitative analysis of the energy efficiency component of the Green Gauge programme has been conducted to enable AECI to determine the critical factors that could lead to the success of future implementation of energy efficiency programmes. An evaluation of the effectiveness of the energy component of the Green Gauge programme will provide AECI with valuable insights to be able to make this decision.

The study also informs whether such a programme should be rolled out to other manufacturing sites within the AECI group and other manufacturing companies in South Africa and if so the learnings and insights that can be applied from the energy efficiency component of the Green Gauge programme.

1.3 Rationale for the study

Funding, support and subsidies from the UK Department of International Development, The National Department of Energy and the Department of Trade and Industry in the form of the Private Sector Energy Efficiency Programme (National Business Initiative, 2015a) and National Cleaner Production Centre of South Africa (NCPC-SA) (NCPC-SA, 2014) stimulated industry in South Africa to implement energy efficiency programmes, while some industries took it upon themselves to implement their own energy efficiency programmes. The Private Sector Energy Efficiency Programme was concluded in November 2015, while the NCPC-SA programme continues to run but with uncertainty about when the programme will conclude (the latest case study reported was in 2015). It is evident that these programmes have potentially limited life spans, therefore it is imperative to assess the effectiveness of such programmes in order to channel and focus resources appropriately in future endeavours.

Moreover there is currently no mandatory requirement for participating industries to show that they have put in place the necessary processes and systems to continue implementing energy efficiency programmes – therefore an assessment on the effectiveness is critical to motivate industries to continue with implementation and monitoring of their programmes in South Africa.

Energy efficiency projects have been reported to a large extent in the literature globally. However, what is missing is actually assessing the effectiveness of these programmes in terms of both a qualitative and quantitative evaluation in the manufacturing sector in South Africa. While there are several research studies globally focusing on the quantitative and qualitative evaluation of energy efficiency projects, there is a paucity of information in the South African manufacturing sector. In South Africa energy efficiency performance is reported on extensively, in annual reports and case studies from national energy efficiency programmes, while peer reviewed studies on energy efficiency are lacking. This study provides key information relating to the extent or potential for energy savings per technology, cost criteria for implementation, and insights from programme managers, which is lacking in the South African manufacturing sector, to enable companies to properly formulate strategies and plans for their own energy efficiency programmes.

1.4 Significance of the study

The study is important as it provides a blueprint and potential framework for the programme managers of other manufacturing companies within AECI, as well as external companies in the South African manufacturing sector to be able to assess challenges and address them with senior management (Managing Directors, Operations Directors, etc.) or teams, before embarking on such a programme. The assessment provides senior management with insight into how the programme managers experienced the programme and will give senior management an appreciation of the risk elements in the programme. The assessment will offer guidance and insights to companies in determining which energy efficiency projects and technologies to focus on based on various criteria.

1.5 Research objective

The objectives of this study are:

- to assess the main drivers and barriers of energy efficiency globally and in South Africa;
- to identify the various components and extent of energy efficiency used in the manufacturing sector; and
- to evaluate the effectiveness of energy efficiency programmes using AECI's Green Gauge programme as a case study and provide a model for companies wishing to embark on a similar programme.

1.6 Scope of the study

The scope of this study was limited to AECI's Green Gauge energy efficiency programme implemented at 16 of its manufacturing sites in South Africa. The outcomes of this study may not be generalisable as AECI is a very diverse business offering various services and products. The outcomes achieved in this research may not be applicable to other industries as they may have different organisational structures to AECI. They can, however, be used to determine the critical factors that could lead to the success of similar programmes.

1.7 Research strategy

The research strategy involved steps aimed at understanding the research problem and addressing the research objectives to determine the effectiveness of AECI's Green Gauge programme.

The research strategy is depicted in Figure 1.1.

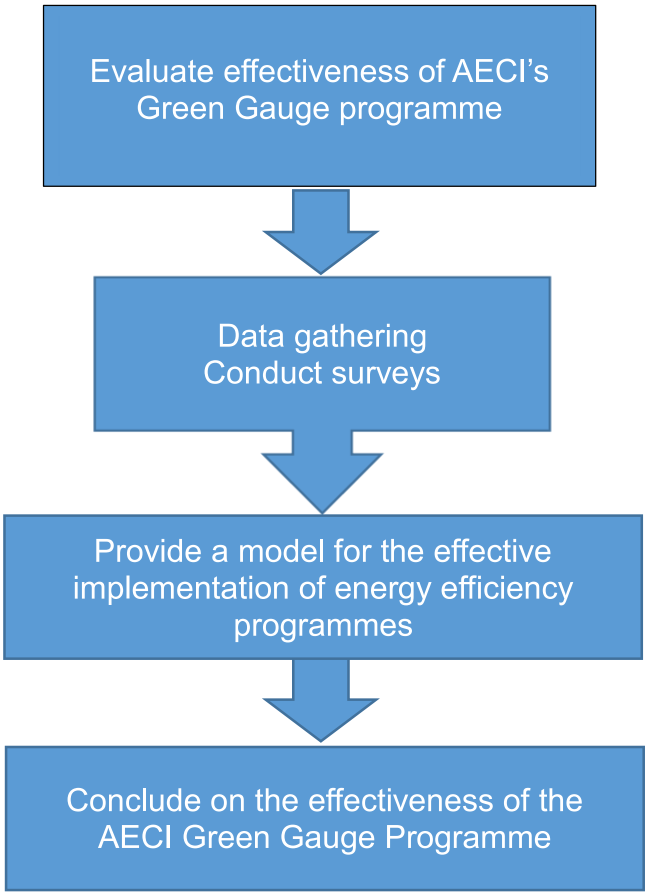


Figure 1.1: Research strategy

The first step in the research strategy involved reviewing the most recent academic literature relevant to energy efficiency in the manufacturing sector both globally and locally, namely the drivers and barriers. In taking this step the drivers and barriers at a local and global level were understood giving effect to the level of implementation of programmes.

The second step of the literature review was to identify various components of energy efficiency used in the manufacturing sector by reviewing global and local industrial practices in energy efficiency programmes, implementing key performance indicators for energy efficiency in the manufacturing sector, and energy standards and models used in the manufacturing sector. In taking this step the level of practices, in terms of the maturity of implementation employed in the global and local landscape, was understood.

Step 3 involved gathering data, conducting surveys and thereafter evaluating the information obtained from AECI companies to determine if the Green Gauge programme was effective in terms of the energy efficiency projects implemented. A number of safety, health, environmental (SHE) practitioners, engineers and operations managers (also referred to as programme managers) in the companies were requested to respond to the questionnaire aimed at understanding the various drivers and barriers and to assess if the programme was effective in their view.

Step 4 of the research strategy involved assessing the data and questionnaire responses to deduce on the effectiveness of the energy component of AECIs Green Gauge programme.

The final steps conclude on the study and provide recommendations and a model for future similar energy efficiency programmes.

1.8 Thesis outline

Chapter 1 outlines the background of the study setting the context and the emergence of the research idea. The problem statement is then described setting the reason for the study. The rational for the research, as well as the research objectives follows. Thereafter the significance is demonstrated and the scope is defined in terms of its limitations and assumptions.

Chapter 2 outlines the literature review firstly describing the key global and local energy efficiency drivers and barriers and thereafter outlining the global industrial practices in energy efficiency programmes. Thereafter a focus on the South African manufacturing sector energy efficiency programmes is provided and current standards and models used in the manufacturing sector are described along with best practice energy efficiency initiatives and associated savings.

Chapter 3 presents the AECI case study, in terms of the energy efficiency component of the Green Gauge programme implemented at manufacturing facilities.

Chapter 4 focuses on the research design and methodology. This chapter covers the methodologies employed to address the three objectives of the study.

Chapter 5 presents the results of the study where an in-depth analysis of the results is provided. In addition a model is presented providing key steps on the effective roll out of an energy efficiency programme in the South African manufacturing sector.

Chapter 6 is the conclusion and recommendations section. A synthesis of the results, gaps and recommendations for improvement are presented.

Chapter 2 – Literature Review

2.1. Introduction

Globally, energy efficiency plays an important role in reducing energy consumption to address global issues such as climate change and energy security (Parker & Liddle, 2016:38). As climate change is said to be caused by anthropogenic factors, reducing greenhouse gas emissions is a major factor in addressing climate change and one of the predominant ways emissions can be reduced is through energy efficiency interventions. At the 22nd Conference of the Parties[3] (COP 22), it was evident that we cannot only reduce emissions with energy efficiency, but power can be provided to those without access by redirecting the energy that is saved. In addition the need to focus on energy efficiency is only going to increase as Africa develops given the importance of electric power for economic development (ABB, 2016:1). The role of energy efficiency is important as countries look towards addressing their goals to reduce greenhouse gas emissions by improving their energy usage. Energy security is a critical concern globally due to the finite supply of resources and price fluctuations in commodities such as oil and coal.

Use and production of energy contributes approximately two thirds of greenhouse gas (GHG) emissions globally. Therefore the energy sector must be a key part of the global action to address climate change (International Energy Agency (IEA), 2015:3). The energy sector provides a significant amount of this energy to the manufacturing sector of which energy efficiency, a key way in which energy consumption can be reduced, is explored further in the following sections.

This chapter provides a review of the adoption of energy efficiency in the global and local manufacturing landscape. Firstly the key global and local energy

[3] The 22nd Conference of the Parties and 12th session of the conference of the parties serving as the meeting of the parties to the Kyoto Protocol took place in Morocco in November 2016. https://unfccc.int/process-and-meetings/conferences/past-conferences/marrakech-climate-change-conference-november-2016/cop-22

efficiency drivers and barriers are discussed which is important in providing the key reasons for extent of implementation of projects in industry across first world and developing countries. Global industrial practices in energy efficiency are then described providing insight on key energy efficiency technologies employed and energy management practices in industry. The implementation of key performance indicators in industry in the energy efficiency space is important in terms of effectively measuring energy efficiency and is discussed later in this chapter. A review of South African energy efficiency case studies in the manufacturing sector is conducted to indicate the maturity of adoption of energy efficiency and lastly a summary of energy standards used in the manufacturing sector is outlined indicating the span of energy management systems employed in this sector.

2.2. Key global and local energy efficiency drivers and barriers

Drivers are defined as the ‘stimuli for energy management in manufacturing that highlight motives of companies to achieve improved energy efficiency in manufacturing’, while barriers are the predominant inhibitors to implement energy and economic efficient interventions (May, 2017:1468).

A study focusing on literature published from 1995 to 2015 on energy management in manufacturing yielded the following results (See Figure 2.1), in terms of drivers and barriers to energy efficiency in the manufacturing sector (May, 2017:1468).

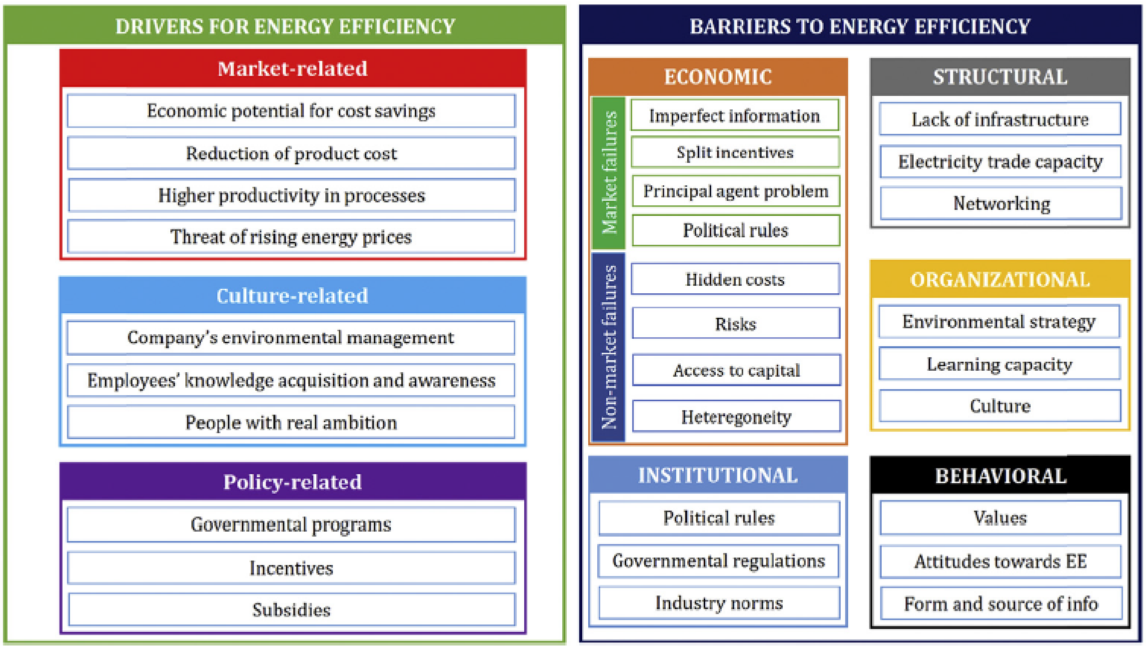


Figure 2.1: Drivers and barriers identified to implementing energy efficiency in the manufacturing sector
Source: May, (2017:1468)

The above assessment has been found to be predominantly the case when assessing the literature up to 2018 for this study. The key, cross-cutting barriers and drivers identified from the literature review for this study are discussed below:

2.2.1. Energy efficiency drivers

Drivers of energy efficiency can be considered as the factors that promote private investment in energy efficiency (Cagno & Trianni, 2013:277).

A systematic literature review covering the period 1998 to 2016 identified the main categories of drivers being economic, management and organisational, market and government policy (Solnordal & Foss, 2018:14). These are closely aligned with the drivers depicted in Figure 2.1.

In review of the literature a number of drivers are cited in the manufacturing sector under the categories depicted in Figure 2.1; some of the common cross-cutting drivers identified are efficiency (cost savings), policy, energy pricing, economic development and technological progress, market pressure, and organisational. The drivers influencing the adoption of energy efficiency interventions will first be explored both globally and in South Africa looking at both developed countries, as well as emerging economies.

Efficiency (financial benefits)

Reviews of the literature suggest that there is typically a positive relationship between financial and environmental performance, at least under some circumstances. Circumstances include investing in 'low hanging fruit' that can be profitable and easily harvested or the company owns complementary assets that enables it to undertake profitable environmental opportunities and the company has the required capabilities to implement environmental initiatives (Dowell & Muthulingam, 2017:1287-1288). While this talks to broader environmental issues, it can also be applied to energy efficiency projects being a sub category of environmental interventions.

The literature was also reviewed in terms of efficiency being a driver at country level. Cost reduction or efficiency resulting from lowered energy use was the most highly ranked driving force for energy efficiency improvement in Ghana (Apeaning & Thollander, 2013:209), which falls into the developing country category.

The driving forces for energy efficiency improvement are depicted in Figure 2.2 for Ghana's Industrial sector depicting cost reductions as the highest driver:

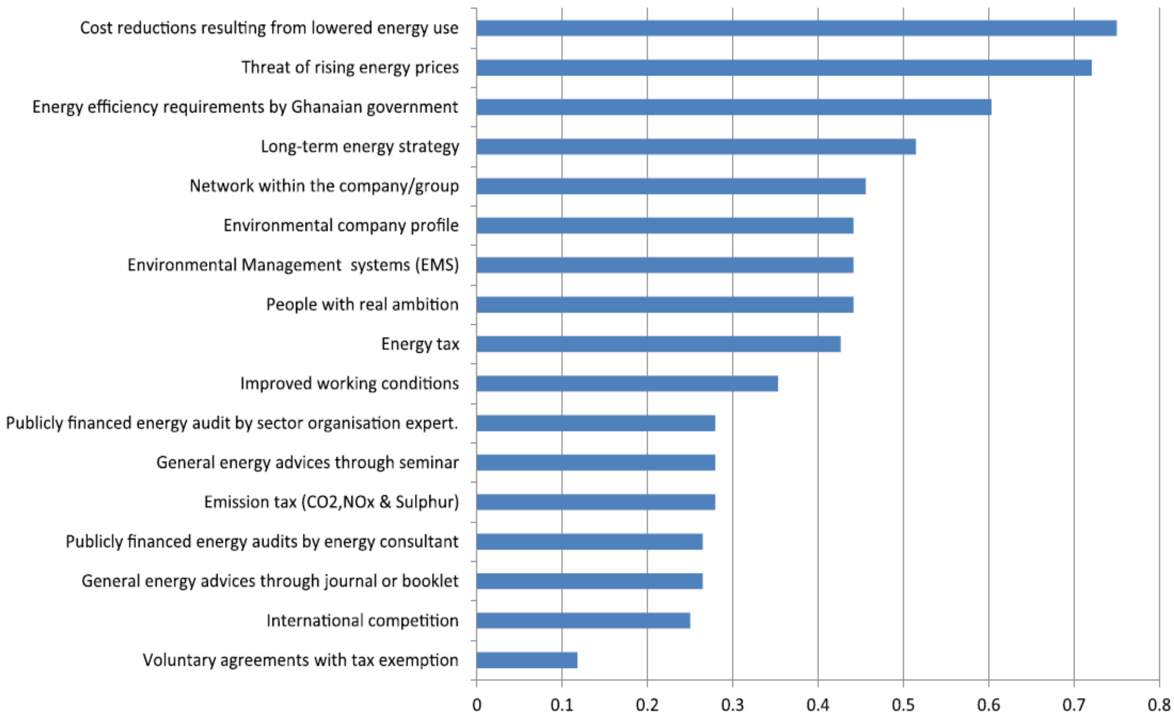


Figure 2.2: Ranking of driving forces for energy efficiency improvement
Source: Apeaning & Thollander, (2013:209)

In another study conducted with a sample of 75 countries, including the USA and China, efficiency was again identified as the major driver responsible for decreasing energy intensity (Parker & Liddle, 2016:39). In fact, for the Organisation for Economic Co-operation and Development (OECD) countries' efficiency was still a major driver for reduction of energy intensity when this study was conducted in 2016 and this has been true since 1980 (Parker & Liddle, 2016:43).

While it is expected that efficiency or cost saving would be a major driver in mainly developing countries, the literature also identifies this as a major driver in developed countries such as the Netherlands. Based on a survey of 135 Dutch enterprises across nine industrial sectors, it has been highlighted that cost savings realised through reduced energy use and the implementation of policies (e.g. subsidies and fiscal arrangements) were major driving forces toward the adoption of energy efficient technologies (Cagno & Trianni, 2013:278).

The cost efficiency driver was also a predominant driver for the Swedish industry. However, it is worth noting that although cost reduction is a strong driver, studies evaluating actual energy efficiency investments have found that capital investment cost and the payback period are also determining factors (Solnordal & Thyholdt, 2017:2806).

Policy

The Paris Agreement[4], reached at the Conference of the Parties in December 2015, brought all nations into a common cause to undertake considerable efforts to combat climate change (Paris Agreement, 2019). Amongst the 195 parties, South Africa was one of the countries that signed the agreement committing to reduce its greenhouse gas emissions. One of the principle ways to reduce greenhouse gas emissions is through implementing energy efficiency interventions.

In the European Union (EU) energy efficiency is one of the principle instruments in achieving the objectives of the EU Energy and Climate Package triad by 2020 requiring countries to reduce greenhouse gas emissions by at least 20% from 1990 levels by 2020, increase renewable energy sources by at least 20% of the gross energy consumption and reduce energy consumption by 20% when compared to projected trends (Hrovatin et al, 2016:475). The European Energy End-use Efficiency and Services Directive came into force in 2006 and proposed a reduction in energy use of 9% in each member state which is required to be achieved by the ninth year of implementation of the directive (Thollander et al., 2007:5774).

Policy is a key driver to encourage small to medium size manufacturing companies to implement energy efficiency measures. In an analysis of Sweden’s Project Highlands, an industrial energy efficiency programme targeting 340 small, medium enterprises (SMEs) between 2003 and 2008, it

[4] The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change signed in 2016.

was found that energy efficiency policy was required to be strengthened in order to target companies that fall in the SME category (Thollander et al., 2007:5782).

This finding was confirmed in another research study of 848 Slovenian firms for the period 2005 to 2011 where it was stated that policy measures are required for less energy intensive SMEs as the gap is less likely to exist in energy intensive, well-performing and large firms (Hrovatin et al., 2016:475).

An important policy finding from assessing manufacturing companies in OECD countries, was that climate change and energy policy aimed at reducing emissions from fossil fuels can result in significant reductions in energy use for energy intensive sectors (Steinbuks & Neuhoff, 2014:354). This is due to the link between energy and CO_2 emissions.

In contrast in China, one of the most energy intensive countries, it was found that the energy intensive sector still has significant potential for energy savings despite policy efforts (Yang & Yang, 2016:1395). Evaluation of China's Energy Saving and Emissions Reduction (ESER) policy in its 10^{th} and 11^{th} Five-year plans (FYP) shows that only 4 of the 15 energy intensive industries or sub-sectors achieved significant energy efficiency improvements in the 11^{th} FYP compared to the previous phase. Policies were less effective for the other 11 sub-sectors which showed minor energy efficiency improvements for the entire decade that the policy was in place (Yang & Yang, 2016:1401).

Over the years South Africa's energy performance score has systematically declined. This is mainly due to the economic structure changing towards more energy intensive, low value added services (Aye et al., 2018:1477). The policy and regulatory framework around energy efficiency has significantly evolved in the past few years in South Africa. However, while this is so, the key policies around energy efficiency are not yet mandatory. A summary of the key policy and regulations driving implementation of energy efficiency in South Africa is outlined below.

One of the policy instruments driving energy efficiency is the National Energy Efficiency Strategy (NEES). The NEES was released in 2005 'to explore the potential for improved energy utilisation through reducing the nation's energy intensity (thus reducing greenhouse gas emissions) and decoupling economic growth from energy demand' (Modise, 2013: 3). An overall energy intensity reduction target of 12% was set across various sectors, including Industry and Mining (15%), Commercial and Public buildings (15%), Residential (10%) and Transport (9%) for the period 2005 to 2015 using the 2000 year as the baseline.

The NEES post 2015 is based on the 25 Energy Efficiency Policy Recommendations developed by the International Energy Agency (IEA). The IEA, 2008 estimates that the proposed actions could save as much as 7.6 gigatonnes CO_2/year by 2030 (Modise, 2013: 18). The policy recommendation by the IEA for industry is to implement:

- 'Energy management systems
- High efficiency industrial equipment and systems
- Energy efficiency services for Small Medium Enterprises
- Complimentary policies to support industrial energy efficiency' (Modise, 2013: 20).

A monitoring system was established in 2014 to monitor progress made towards achieving the energy intensity reduction target set by the 2005 NEES. The results show that significant progress was made between 2000 and 2012, exceeding expectations in most sectors. For the industry sector a reduction of 34.3% was achieved exceeding the 15% target significantly (Republic of South Africa, 2016:1). This is a clear demonstration that the strategy together with the monitoring and evaluation programme was a driver towards not just reducing energy consumption, but implementing energy efficiency interventions.

The post 2015 NEES aims to build on the achievements by 'stimulating further energy efficiency improvements through a combination of fiscal and financial incentives, a robust legal and regulatory framework, and enabling measures' (Republic of South Africa, 2016:7). The new strategy will focus on the period

2015 to 2030. The targets for Industry and the mining sector are 16% reduction in weighted-mean specific energy consumption and 40 petajoule (PJ) energy saving from specific energy saving interventions by mining companies (Dos Santos, 2017:6).

The Integrated Energy Plan (IEP) was published in 2003 (Republic of South Africa, 2003:1-29). The intention of the IEP was to provide a roadmap of the future energy landscape of South Africa to guide future energy infrastructure investments and policy developments. The IEP takes into account existing policies and various scenarios. One of key objectives of the IEP is promoting energy efficiency.

The Carbon Tax Act came into effect on 01 June 2019 in South Africa. Companies will only be taxed on direct or process CO_2 emissions so any energy efficiency initiatives will not be beneficial from a carbon tax perspective except where there may be a pass through effect onto companies from the electricity generator and fuel manufacturer (Times Live, 2018:1). However, energy efficiency interventions linked to combustion activities, for example using alternative fuels in boilers, will also lead to reduced CO_2 emissions thereby benefiting companies from reducing their carbon tax burden.

The 12L Tax Incentive was introduced in 2013 (Republic of South Africa, 2013b:1-8) and is administered by the South African National Energy Development Institute (SANEDI), a state company created to help accelerate energy projects. The 12L tax incentive continues to be a key part of the Department of Energy’s approach in encouraging improvement in energy efficiency in industry.

Although the South African Government is attempting to encourage investment in energy efficiency through various policy instruments listed above, there is the need to enforce these policies and strategies, as well as conduct monitoring and evaluation on a continuous basis in order to achieve the targets set (Aye et al., 2018:1479).

Policy is a key driver towards implementing energy efficiency measures and in developing countries; if policy measures are put in place to help companies invest in energy efficiency, it has been found that these companies will be more likely to invest in energy efficiency interventions in the future (Cantore, 2017:751).

Energy prices

In the last 20 years there has been an increase in energy prices of up to 100% in Germany (Apostolos et al., 2013:629). Increasing energy prices have also become a global trend which has been a key driver towards improvements in energy efficiency in the manufacturing sector (Parker & Liddle, 2016:38).

For Colombia's manufacturing sector, while energy prices are one of the key determinants towards energy efficiency performance, it was found that electricity prices were of less significance in both the non-energy intensive and energy intensive sectors for the period 1998 to 2005 (Martinez, 2010:557).

In a study looking at what impacts increased energy prices have on manufacturing sector's energy consumption (OECD countries) and how prices impact on energy intensity changes, the findings indicate that increasing energy prices can lead to improvements in energy efficiency. In studies, including the manufacturing sector, prices played a key role in reducing energy intensity, in particular through technology use (Parker & Liddle, 2016:39).

India, one of the highest energy consuming countries next to China, has experienced increases in energy pricing over the past few decades although it still has low electricity prices relative to other countries. In a comprehensive analysis of seven energy intensive manufacturing industries, evaluating their energy demand behaviour, during 1973 to 2011, it was found that increases in energy price led to reduction in energy demand. But, technological progress led to significant energy saving (Wang &Li 2014:957). However, looking at the broader manufacturing sector across Indian states for the period 1998 to 2004, it was highlighted that low energy pricing did not incentivise manufacturing companies to invest in energy efficiency measures (Mukherjee, 2008:671).

According to Kohler (2014:524), South Africa has had a history of low and stable electricity prices and its electricity efficiency is therefore lower on average than other countries which have had significant electricity price increases. He adds that improvements up to 2014 in energy efficiency have, as a consequence, been small by international standards. While electricity prices would have been stable up to 2014, there has certainly been significant increases in electricity prices in more recent years and are set to increase in the future. The National Energy Regulator South Africa (NERSA) granted a price hike for the power utility, Eskom, in April 2019 allowing it to raise its prices by 25% over the next three years. Statista compiled data on the average price of different countries at the end of 2018. Figure 2.3 shows where South Africa fits in.

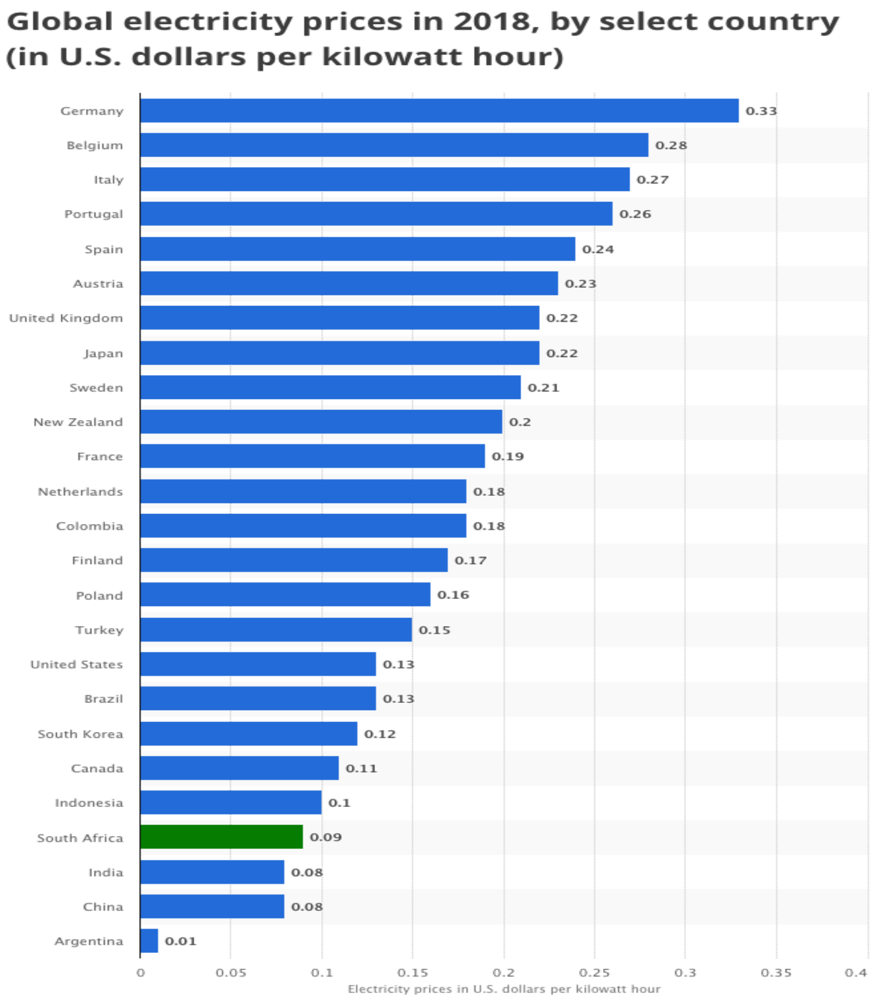


Figure 2.3: Global Electricity prices in 2018 by country

Source: Global Power Prices, 2018

While South Africa is still among the lowest electricity prices globally, along with India and China, this is set to change in the future and rising electricity prices could be a driver towards industry implementing energy efficiency interventions.

Market pressure

According to (Parker & Liddle, 2016:41) additional determinants that may influence energy intensity are increased investment in new technologies and increased competitive pressures from openness which lead to reduced energy intensity in an effort to remain competitive. The latter can be in the form of more transparent reporting of energy efficiency in stakeholder reports such as sustainability and integrated reports.

Market pressure is typically associated with larger firms which are generally exposed to stronger competition in a global environment. These firms also have higher energy usage compared to medium and small firms, so greater scrutiny is usually placed on these firms (Solnordal & Thyholdt, 2017:2806).

In an assessment of Ghana's drivers in the manufacturing sector the factors towards implementing energy efficiency measures were organisational and financial growth, sustainability of which environmental strategy is key, significant increases in electricity prices and cost savings. However, it was interesting that market pressure was also a key driver as it was stated that organisations typically wish to trade or conduct business with organisations that have established environmental management systems in place (Rasmussen, 2015:1-19).

Pressure from the market certainly depends on the type of industry, region and the maturity of the market. For example, it was found that the most important drivers for the Chinese Automotive Industry were regulatory requirements and market pressure (Fargani et al., 2016:492).

While market pressure does not appear to currently be a major driver towards implementing energy efficiency interventions, there are signs that it is increasingly becoming a driver in certain industries in developing countries.

Economic development and technological progress

Although not significantly referred to in the literature economic development and its associated technological progress is seen to be a driver towards implementing energy efficiency interventions more especially in countries such as China and India.

For the period 1970-2008 two industrialised countries, China and Mauritius, who have used manufacturing as a means of economic development were the best performing countries from an energy productivity perspective. On the other hand, two large developing countries, Brazil and Indonesia, have experienced worsening energy productivity in manufacturing although economic performance has improved (Parker & Liddle, 2017:340).

In a comprehensive analysis of seven energy intensive manufacturing industries, and evaluating their energy demand behaviour during 1973 to 2011, it was found that technological progress led to significant energy savings (Wang & Li, 2014:957). Linked to technological progress is innovation in the energy efficiency space. Companies that are more energy intensive usually pursue research and development in energy efficiency (Solnordal & Thyholdt, 2019:986).

Those organisations that usually have higher annual growths are those that also have policies in place for energy efficiency programmes, invest in energy efficient technology, offer more energy efficient products to their customers and can demonstrate higher energy savings (Gouws et al., 2012: 63). In Colombia significant foreign investment in Colombian manufacturing industries focusing on machinery, plant and equipment, resulted in a significant decrease in energy intensity for the period 1998-2005 (Martinez, 2010:557).

This driver appears to be a function of the type of region and extent of economic development. In addition, new technology implemented is far more energy efficient than older technology and this would be one of the main factors towards a decline in energy intensity.

Organisational drivers

Internal organisational drivers are vital in improving environmental performance. According to a systematic literature review for the period 1998 to 2016, managerial and organisational factors contributed towards the greatest direct benefits in terms of improvement in energy efficiency (Solnordal & Foss, 2018:14).

Competency of the workforce is frequently considered an important driver towards implementing energy efficiency measures. Respondents from companies in a Swedish manufacturing study that had been successful in adopting energy efficiency interventions, indicated that one of the key driving forces were people with ambition. These companies had executives who had clear environmental goals (Rohdin & Thollander, 2006:1842). Another study of the Indian manufacturing sector confirms that 'a higher quality labour force associates with higher energy efficiency' (Mukherjee, 2008:671).

The recommendation from a study from SMEs in the United States is to target managers who are involved in an operationally-focused position but are also relatively senior, as it was found that involvement of top managers without an operational role had little or small effect on adoption of energy efficiency measures, while top operational manager involvement increases the adoption of measures significantly (Blass et al., 2014:560). In fact it was found that 'top management's commitment is the most important constraint in terms of reducing a firm's likelihood to invest in energy efficiency measures according to a study of the manufacturing sector in Vietnam, the Philippines and Moldova (Cantore, 2017:751).

An interesting and very relevant finding relating to organisational factors is that implementing lean manufacturing practices will result in improvements in energy efficiency due to improving workforce efficiency and capacity utilisation (Khalaf et al., 2011:1892).

2.2.2. Energy efficiency barriers

Energy goals are enshrined in a set of international sustainable development goals (SDG) agreed on in 2015 to curb poverty and end hunger. The energy goals underpin the 2015 Paris climate change agreement to keep global warming to well below 2 degrees Celsius above pre-industrial levels by reducing emissions. According to Kyte (2017), head of Sustainable Energy for All and special representative of the U.N. Secretary General, energy efficiency should be the first intervention as it is the cheapest, easiest and fastest way to meet Sustainable Development Goal 7 and to be on the right path towards implementation of the Paris Agreement. However, many countries are lagging in the area of improving energy efficiency (Times Live, 2017).

Barriers towards improving energy efficiency have been assessed in the industrial sector both globally and locally. The main categories of barriers were identified as economic, institutional, structural, organisational and behavioural (May et al., 2017:1468). The predominant cross cutting barriers identified from the literature review in the manufacturing sector are closely aligned with the main barriers identified. Access to capital, other priorities requiring capital investment, lack of technical skills, technological barriers, environmental management systems, behavioural and awareness are the predominant barriers identified and which are discussed below.

Figure 2.4 shows the results of a survey examining barriers to improving energy efficiency in Ghana's industrial area.

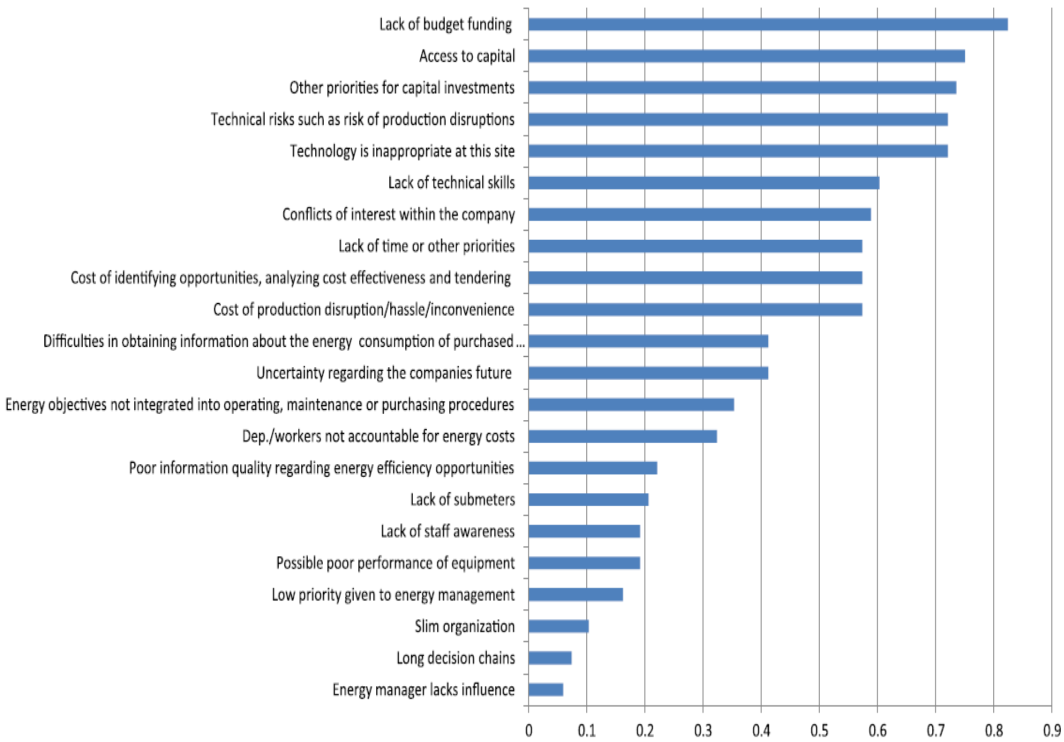


Figure 2.4: Ranking results of barriers to improving energy efficiency

Source: Apeaning & Thollander, 2013:208

The common cross cutting key barriers from the literature review are discussed below.

Access to capital

The 'industrial energy efficiency gap' in developing countries is due to market failures such as informational barriers and financial barriers impacting on access to capital for energy efficiency projects. What makes the gap more pronounced than that of developed countries is the existence of fragile economies, poor energy infrastructure, the lack of policies, etc. (Apeaning & Thollander, 2013: 212).

In an economy that is flat or close to experiencing recession such as South Africa has experienced over the past two years (2017 to 2019) companies generally struggle to access capital for various capital projects. This is the case for many developing countries.

In a study aimed at investigating the barriers and forces driving energy efficiency improvements in the industrial sector in Ghana, most of the respondents cited a lack of access to finance as a very important inhibiting factor to the implementation of energy efficiency in their firms (Apeaning & Thollander, 2013:208). This is to be expected in a country, such as Ghana, a developing country where funding for projects in general can be expected to be difficult to access.

The cost of implementing projects may be high and does not present a good business case in the short term; the return on investment is poor and does not meet business requirements. Most South African organisations require projects to have a shorter payback period, which is typically less than 5 years and on average between 1 and 3 years (National Business Initiative, 2015b:11) although this is against the principles of World Business Council for Sustainable Development which encourages organisations to accept projects with longer payback periods for energy efficiency and eco efficiency projects.

In the eThekwini (KwaZulu Natal, South Africa) manufacturing sector, the most significant factor inhibiting implementation of energy efficiency measures was cost-related. It was found that while in some cases energy efficiency technology offers benefits with respect to reducing costs, in other cases energy efficiency technologies were priced outside the market (Singh & Lalk, 2016:301).

A survey was conducted in which respondents were asked to assess the extent to which they adopted energy efficient technologies (using a scale 0 (not adopted) to 1 (extensively adopted). The results of this survey are depicted in Table 2.1 with Power Factor correction and use of energy efficient computers, photocopiers and other office equipment achieving the highest score. These appear to be the lowest hanging fruit.

Table 2.1: The main implemented energy efficiency measures and their corresponding average score

	Main energy efficiency measures	**Average score**
Electrical	Power factor correction; Use of energy efficient computers, photocopiers & other office equipment	0.39
Lighting	Replacement of 38 mm fluorescents with 26 mm; Replacement of tungsten filament lamps with compact fluorescents; Use of high frequency fluorescents in new and replacement fittings; Optimise the use of natural light.	0.36
Compressor and pump	Use of centrifuge pumps and throttle controls; Use of appropriate and efficient motors (or variable speed motors).	0.33
Heat processing and boiler plant	Proper insulation of distribution pipes, valves and boiler; Accurate control of furnace temperature, pressure and air/fuel ratio; Use of boiler refractory; Installation of thermostatic radiator valves.	0.17

Source: Apeaning & Thollander, 2013: 210

From the survey conducted it is apparent that low cost interventions such as electrical and lighting were implemented much more than high cost initiatives such as energy efficient equipment (compressors and pumps and heat processing and boiler plants). Interventions in the electrical and lighting space also have short payback periods. Financial institutions focus on the financial aspects in terms of their investments: those projects with good payback, and return on investment are selected to energy efficient projects that have a higher acquisition cost (Gouws et al., 2012: 59).

Even in developed economies such as the Italian manufacturing sector, it was found that small enterprises appear to struggle from low capital availability barriers, therefore having greater difficulty than medium or large enterprises in investing in technologies (Trianni et al., 2013:457).

Other priorities requiring capital investment

Energy efficiency projects are often not regarded as being directly aligned with the key challenges a business faces such as satisfying customers and growing sales (Kleindorfer, 2010:4).

In developing countries legislation and policies relating to energy efficiency are not as mature as developed countries and often organisations energy efficiency policies follow this maturity curve. Therefore the business strategy often does not make reference to energy efficiency. Organisations' energy efficiency policies and programmes are still in development while governments do not often encourage the development through legislation, policies and national strategies (Gouws et al., 2012: 64).

Lack of technical skills

The lack of technical skills was highlighted as a significant barrier in at least three studies. As was expected this barrier featured as a major barrier in research studies in developing countries and did not appear in research studies associated with developed countries.

In an analysis conducted of Ukraine commercial and industrial firms, it was suggested that behavioural constraints such as lack of technical knowledge or skills hamper the adoption of energy efficient technologies in commercial and industrial firms leading to under investment in these technologies. This was identified as a major barrier towards adoption of energy efficiency interventions (Hochman & Timilisina, 2017:23).

In a case study of Ghana's largest industrial area, involving 34 companies, lack of technical skills was in the top 6 barriers out of 22 that were assessed. The majority of the firms interviewed lacked skilled technical personnel to be able to evaluate the performance of energy efficient interventions. This was a serious limitation which inhibited the companies from adopting technologies (Apeaning & Thollander, 2013:208).

Research pertaining to Slovenian manufacturing firms found that one of the crucial barriers was a lack of technical energy experts and skills, identified as the most important obstacle towards implementation of energy efficiency interventions (Hrovatin et al., 2016:477).

The above cases all apply to developing countries, while in the case of a developed country involving Norwegian manufacturing companies, it was found that higher education of staff served as a driver towards implementing energy efficiency measures. In addition research and development (R&D) by well-educated R&D staff assist in energy efficiency innovation (Solnordel & Thyholdt, 2017:2805).

Emerging economies have the challenge of low levels of technical expertise and while it takes time to upskill employees and bring in needed technical resources, the benefit of having well trained staff certainly drives the energy efficiency agenda.

Technological barriers

One of the top 5 barriers listed in the case study of Ghana's largest industrial area was that technology was inappropriate for most of the companies interviewed.

Many of the energy efficiency opportunities depend on new technologies and infrastructure at manufacturing sites in many countries. Technology and manufacturing sites may be old and cannot be retrofitted. In addition, a constant supply, as well as good quality power, is necessary to ensure that new and efficient technologies operate optimally. A common problem in emerging countries is regular voltage fluctuations and power failures (Praetorius & Bleyl, 2006:1522).

Emerging or developing countries are faced with many technological barriers whereas this may not be the case in developed countries, and as such this poses a major inhibiting factor towards the implementation of energy efficient technology.

Environmental Management Systems

The relationship between energy efficiency and economic performance is often assessed in the industrial sector. Research based on the Spanish and Slovenian subsamples of a wider manufacturing survey show that there is no clear relationship between energy saving technologies and economic performance. There is, however, a significant positive relationship between energy saving technologies and environmental performance (Pons et al., 2013:135).

There are many studies that test the link between environmental management systems, typically ISO 14001, and business performance. The results are conflicting: some studies find no support for implementation leading to better business performance, however, business performance was not harmed. In a Swedish study of non-energy intensive manufacturing industry, the existence of an ISO 14001 system did not appear to influence the rate of implementation of energy efficiency measures (Rohdin & Thollander, 2006:1842). However, some studies show the negative impact of ISO certification on pioneer, middle-polluting and smaller firms. In contrast to the above, another study showed the adoption of ISO 14001 improves manufacturers' profitability in the fashion and textile industries in terms of return on assets (ROA) and return on sales (ROS) (Pons et al., 2013:135). However, what is clear is that various studies have demonstrated that adoption of ISO14001 helps to reduce all three impacts: natural resource use, solid waste generation and effluent.

The most commonly used measures of business performance are return on equity (ROE), return on assets (ROA), return on sales (ROS), stock price, market share, sales growth and profitability. It is evident that energy saving technologies do not have a clear relationship with economic performance, but do have a positive relationship with environmental performance. This can be viewed as a barrier for companies that will need to spend money to put in place good environmental management systems and not derive an economic benefit from the implementation of a system.

Behavioural and awareness

Cultural or behavioural issues can be a barrier to implementing energy efficiency measures. While it is widely acknowledged that small and medium firms require more focus than larger, more energy intensive firms, behavioural and awareness issues are crucial for SMEs to be tackled (Trianni et al., 2016:1550).

It is imperative that all levels of the operational team are involved in the project or programme from the start. Production workers at the bottom level should be involved in decision making and be acknowledged and rewarded for their efforts (Mahapatra et al., 2017:1114).

These issues affect the first steps of the decision making process preventing firms from not only evaluating energy efficiency measures but even recognising solutions to be implemented (Trianni et al., 2016:1550).

The key cross cutting barriers in industry, access to capital, focus on other business priorities, lack of technical skills, technological barriers, environmental management systems and behavioural and awareness have been considered in detail above and are shown to exist in both developed and developing countries with lack of skills – other priorities requiring capital investment and technological barriers featuring predominantly in developing countries.

The next section focuses on the second objective of the study: To identify the various components and extent of energy efficiency used in the manufacturing sector.

2.3. The various components and extent of energy efficiency applied in the manufacturing sector

Energy is a critical basic need in the industrial sector globally. It was projected that worldwide industrial energy consumption would grow by an average of 1.4% per year from 51,275 ZW in 2006 to 71,961 ZW in 2030 (Abdelaziz et al.; 2010:152). With the industrial sector consuming more energy than any other sector, there is significant opportunity in this sector for implementation of energy efficiency initiatives (Abdelaziz, 2011:154).

In the European Union, energy efficiency is one of the key objectives highlighted in the European strategy for sustainable growth. Industrial energy efficiency is a focus area with Article 8 of the Energy Efficiency Directive requiring member states to use energy audits and energy management systems of a high quality to improve industrial energy efficiency (Fresner et al., 2017:1650).

In South Africa the National Energy Efficiency Strategy (NEES) was released in 2005 ‘to explore the potential for improved energy utilisation through reducing the nation’s energy intensity (thus reducing greenhouse gas emissions), and decoupling economic growth from energy demand’ (Modise, 2013: 3). The NEES post 2015 was based on the 25 Energy Efficiency Policy Recommendations developed by the International Energy Agency (IEA). Two of the key IEA recommendations for industry are to implement energy management systems and implement high efficiency industrial equipment and systems (Modise, 2013: 20).

This section focuses on the extent and application of energy efficiency in the manufacturing sector globally and in South Africa, energy management system application and the use of energy key performance indicators.

2.3.1 The extent of energy efficiency applied the manufacturing sector

Global manufacturing sector

It is reported extensively that there is a high untapped potential of savings in energy consumption in the industrial sector. In 2007 it was reported that the Global Manufacturing sector uses 42% of all electricity generated, accounts for about 75% of the global coal consumption annually, 44% of the natural gas use and 20% of the global oil consumed (Thollander et al., 2007:5774).

The energy efficiency potential in the European manufacturing sector is first discussed due to the large extent of application of energy efficiency in this region as a result of extensive energy efficiency policy implementation.

In the European Union a short term potential of between 10 and 20% potential savings in energy consumption can be realised (Fresner et al., 2017:1650). Another estimate for small and medium enterprises in the industrial sector of the European Union is more than 25% savings in energy consumption (Thollander et al., 2013:636). Some experts indicate that 40% of the savings would require no capital cost (DOE, 2015a/b).

Since 2007 the global economic crisis has resulted in a decline in improvements in energy efficiency in the European industry: a rate of 0.9% improvement in energy efficiency was recorded between 2007 and 2013 vs 1.9% between 2000 and 2007. It was also estimated that only a quarter of the energy savings between 2007 and 2013 is attributable to interventions in energy efficiency and more than half due to a decrease in production (Businge et al., 2018:1).

A study focusing on the Italian manufacturing sector, more specifically on the paper and glass sector, looked at the energy saving potential in these two sectors for the period 2005 and 2015 analysing more than 188 energy efficiency interventions (Businge et al., 2018:1). For the paper sector a savings potential of 16.2% on total energy consumption was estimated (Businge et al, 2018:4).

The highest savings could be realised with interventions on the entire production line for both thermal energy and electricity.

The thermal energy and electricity saving potentials per cluster is shown in Figure 2.5 for the Italian paper manufacturing sector showing the thermal and electricity saving potentials:

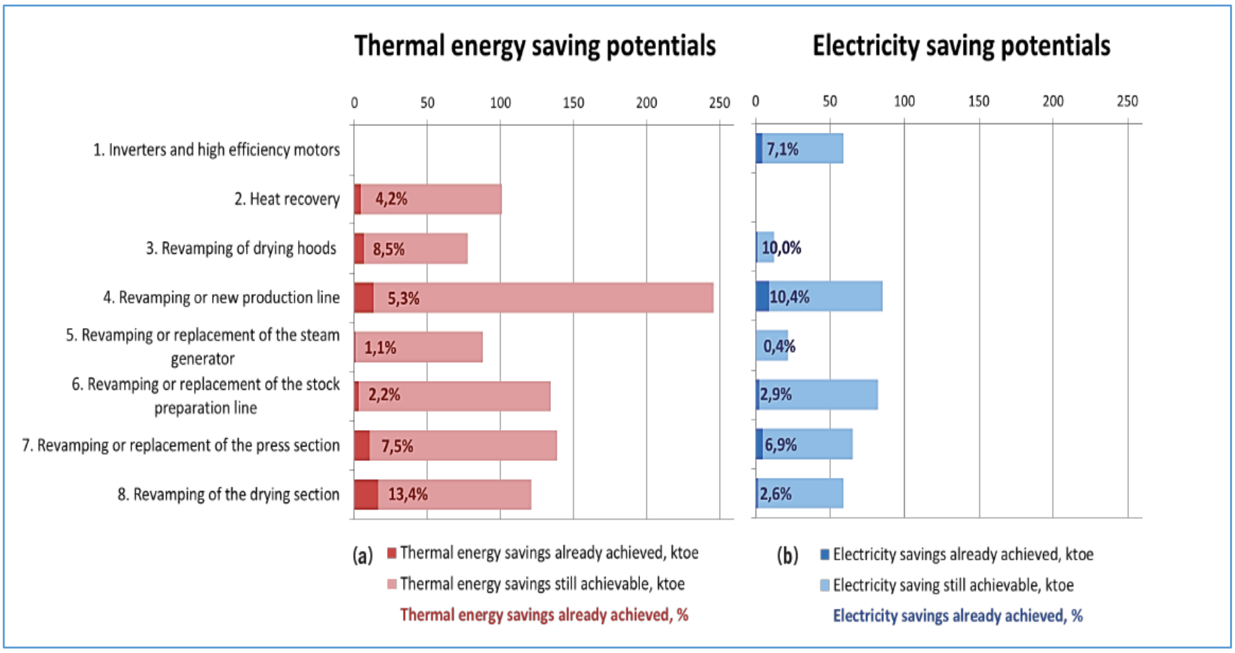


Figure 2.5: Energy saving potential per cluster in the paper sector

Source: Businge et al., 2018:5

For the glass sector (Figure 2.6), a large part of the savings had already been realised, for example revamping of the metal furnace had been achieved at 90% since 2005. However, there was still room for improvement in terms of replacement of the existing melting furnace. It was estimated that there was a saving potential of 8.8% overall for the glass manufacturing sector (Businge et al., 2018:6).

Figure 2.6 shows the energy saving potential per cluster for the glass sector.

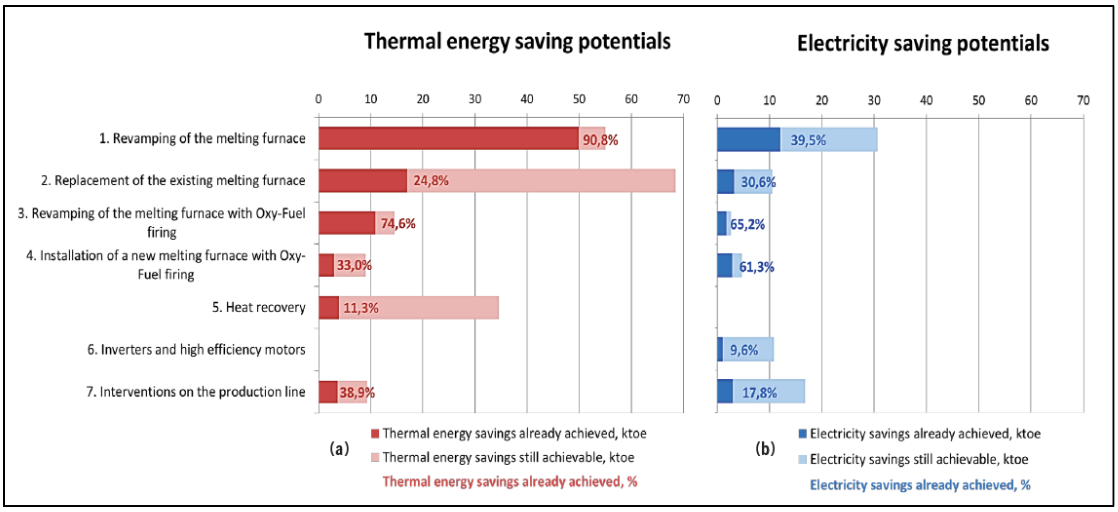


Figure 2.6: Energy saving potential per cluster in the glass sector

Source: Businge et al, 2018:6

Another study in the European Union focusing on energy efficiency in small and medium enterprises where 280 small and medium enterprises (40 industries per European country) were selected to undergo an energy audit, indicates that there is a potential of up to 20% energy savings which can be realised (Fresner et al., 2016:1650). The countries included in the energy audit were Romania, Bulgaria, Spain, Austria, Italy, Slovakia and Cyprus. A variety of sectors were represented, including mining, packaging, plastic, metals, tyre manufacturing, construction, food processing, wood processing and minerals processing (Fresner et al., 2017:1653).

After conducting initial scoping audits, 140 companies were selected for detailed energy audits. The detailed audits resulted in almost 500 opportunities identified which were selected to be implemented. The suggested measures included Compressed air (leakages, optimised pressure level, control), Lighting (control, energy efficient bulbs), motors (control, optimising size), Boilers (condensate return, pressure level, air/fuel ratio, size of boilers, control, pre-heating combustion air and feed water), co-generation and energy recovery (Fresner et al., 2017:1654).

On average it was found that the realised saving was 5% of the energy demand of the industries (Fresner et al., 2017:1654). The major barriers towards implementing energy efficiency technologies were similar to those identified in section 2.2.2 of this literature review, the predominant ones being access to capital and lack of technical skills. The SMEs only committed themselves to a payback period of less than three years for interventions which may explain the average savings of 5%. However, the potential savings of between 10 and 20% included longer payback periods in their analyses (Fresner et al., 2017:1650).

The Swedish manufacturing sector boasted commendable improvements in energy efficiency between 1993 and 2008. Production growth did not result in increases in energy intensity showing that the manufacturing sector produced more with a reduced amount of energy, which is a sign that there were improvements in technology and production standards (Martinez & Silveira, 2012:124). It also indicates the success of energy policies in Sweden. Figure 2.7 shows the decline in energy intensity and CO_2 emissions in the Swedish manufacturing sector.

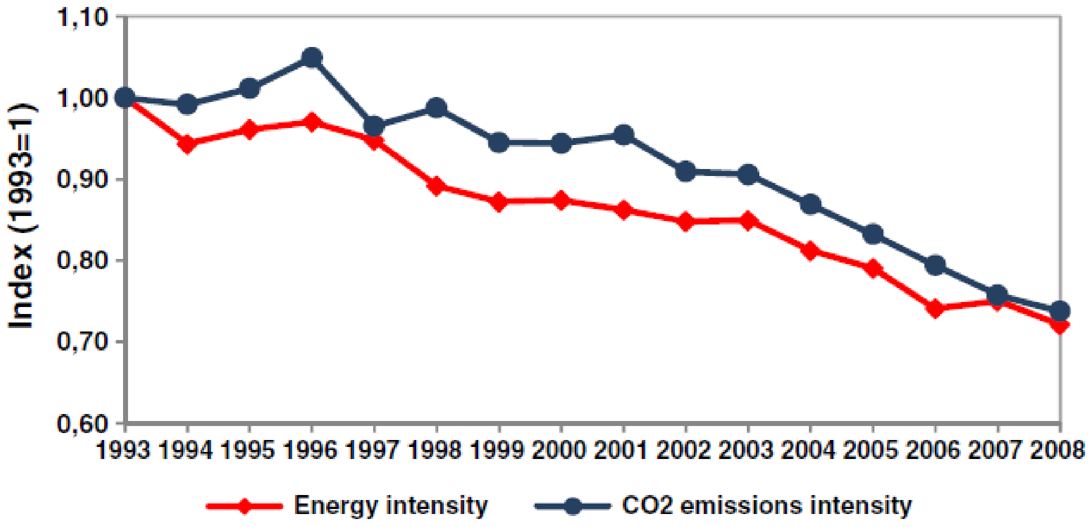


Figure 2.7: Energy intensity and CO_2 emissions intensity as production value in Swedish manufacturing industries, 1998-2003
Source: Martinez & Silveira, 2012:124

The decline in energy intensity is also an indication of the decrease in use of fossil fuels in the manufacturing sector which has partly been achieved through the switch from dirty fuels with high carbon content to cleaner fuels such as natural gas and biomass (Martinez & Sylveira, 2012:125).

Upon review of the Dutch manufacturing industry – a study looking at the energy efficiency trends between 1995 and 2003 – the annual energy efficiency improvements were estimated at 1.3% corresponding to savings of approximately 120 PJ per annum between 1995 and 2003. Saving for electricity was 1.9% and saving relating to fuels and heat amounted to 2.6% per year (Neelis et al., 2007:6125). The sectors considered were chemical sector (fertiliser, chemicals excluding fertiliser), basic metals industry (iron and steel, non-ferrous), paper and building materials. The saving was dominated in the chemical sector.

Moving beyond the European Union, in a study covering some OECD countries and Iran, Austria, Canada, Czech Republic, Denmark, Iran, Japan, New Zealand, Norway, Poland and the United Kingdom – focusing on the petroleum refining sector – it was found that the potential improvements in fossil fuels were greater than for electricity (Azadeh et al., 2007:3805). This correlated with the knowledge that greater than 95% of primary energy consumption was from fossil fuel consumption.

Austria was used as a benchmark or reference based on the Austrian petroleum refining sector having the best relative performance (Azedah et al., 2007:3800). When comparing Iran to Austria, the Iranian refining manufacturing sector needed to reduce its electricity consumption by approximately 90% to be considered as efficient as the Austrian refining sector (Azadeh et al., 2007:3805).

There is a plethora of studies available referring to energy efficiency in the developed countries but few studies relating to developing countries and while it is observed that there is still potential for saving in the manufacturing sector of developed countries, particularly in the European Union, it is expected that there would be a higher potential for energy efficiency saving in developing countries. However, a study looking at the Indian manufacturing sector revealed that the average manufacturing firm would be able to reduce its energy consumption by 14.8% and keep its production output constant (Mukherjee, 2010:940). This is comparable to the European Union manufacturing sector where it is stated that between 10 and 20% potential saving in energy consumption can be realised (Fresner et al, 2017:1650). If output is expected to grow, Indian manufacturing firms will be able to reduce energy consumption and increase production by 3.4% per annum given the prevailing technology (Mukherjee, 2010:940). If India intends to reduce energy efficiency even further, it would require enhancing its research and development and adopting more superior technologies. Also the potential for saving varies considerably across the various states, the worst performing states can reduce energy and increase output by as much as 11.16% and 11.88% respectively (Mukherjee, 2010:94). It is also reported that the chemicals, non-metallic minerals and pulp and paper sub-sectors have not demonstrated any signs of energy efficiency in the period 1992 to 2002 showing that there is potential for energy saving in this sub-sector (Jena, 2009:17).

In the case of another emerging economy, an analysis of SMEs in the Turkish manufacturing sector, revealed significant potential for energy saving. The industrial sector in Turkey comprises about 35% of the total energy used which is spread across various sub-sectors, including metallic goods, textiles, clothing and leather goods, wood and furniture, food and drink, paper and others (Onut & Soner, 2006: 384). Industrial use of electricity comprises 52% of the total electricity use. Of the 20 companies surveyed, 6 were the most efficient and used as the reference in the study – 14 companies were relatively inefficient. The most inefficient SME would need to reduce its electricity consumption by 50%, natural gas consumption by 61%, oil by 50% and reduce low pressure gas (LPG) by 62% (Onut & Soner, 2006:393).

By engaging with the manager of some of the inefficient SMEs, some of the potential interventions included a new boiler system, correctly sized motor drives, insulating all pipes and boilers, servicing equipment regularly, identifying gas and steam leaks and repairing equipment (Onut & Soner, 2006:384). While it was acknowledged that there was significant potential to save energy in the SMEs, it was not clear if there was appetite or drivers to enable the implementation of energy efficiency interventions.

Some emerging economies are starting to encourage implementation of energy efficiency in industry through incentive-based programmes and policy; for example the Malaysian government has offered various energy efficiency programmes. However, industries show very little interest in disclosing energy usage in terms of energy efficiency metrics (Fernando & Hor, 2017:63). A study investigating current practices of energy management in manufacturing firms in Malaysia, focusing on ISO 14001 certified firms, found that energy management practices are still immature and only marginal improvements in energy efficiency are evident (Fernando & Hor, 2017:63). In the past the Malaysian Industrial Energy Efficiency Improvement project realised savings of 0.3% of the total industrial demand of energy – this, however, did not have a lasting effect (Fernando & Hor, 2017:63).

In the South American region, studies on the Colombian manufacturing sector dominate the energy efficiency landscape. The industrial energy usage in Colombia, between 1998 and 2005, increased by 6% while the production of the industrial sector increased by 127%. This was due to improvements in energy efficiency (Martinez, 2010:550). In an analysis of 81 industrial sectors, only 26 industries showed an increase in energy intensity (Martinez, 2010:550). The growth in production was predominantly due to investment in manufacturing industries of more than 50% during the period 1998 and 2005. With the investment came new opportunities for technological transfers resulting in a decrease in energy intensity (Martinez, 2010:557). In a comparative study between the German and Colombian non-Energy Intensive Sectors for the period 1998 to 2005, the gap of energy intensity (EI) between Germany (EI: 2.4 GJ/€) and Colombia (EI:3.3 GJ/€) was low due to production patterns being similar between the two countries. In Colombia it was observed that the Chemical and Automotive industries had energy efficiencies greater than 85% (Martinez, 2016:4).

China's energy profile depicts a long and interesting history. Being the world's largest industrial energy consumer, it is important to reflect on the manufacturing sector's energy efficiency trends. China's manufacturing industry accounts for approximately 60% of China's total energy consumption

(Zhao et al., 2014:46). In a comparison between the Chinese and Japanese manufacturing sector's energy profile, it is evident that China has a high potential for energy savings (Zhao et al., 2014:46). If the Chinese government does not adequately manage the economy, the manufacturing energy demand could reach 2594 megatonnes of coal equivalent (Mtce) by 2030. However, if importance is attached to energy efficiency this could reduce to 1114 Mtce by 2030 representing potential saving of 57% (Lin & Chen, 2018:492).

Figures 2.8 and 2.9 show the energy intensity trends of the Japanese and Chinese manufacturing sub-sectors. Japan, being one the most energy efficient economies, serves as a 'real world' example for energy efficient economic development (Zhao et al., 2014:46).

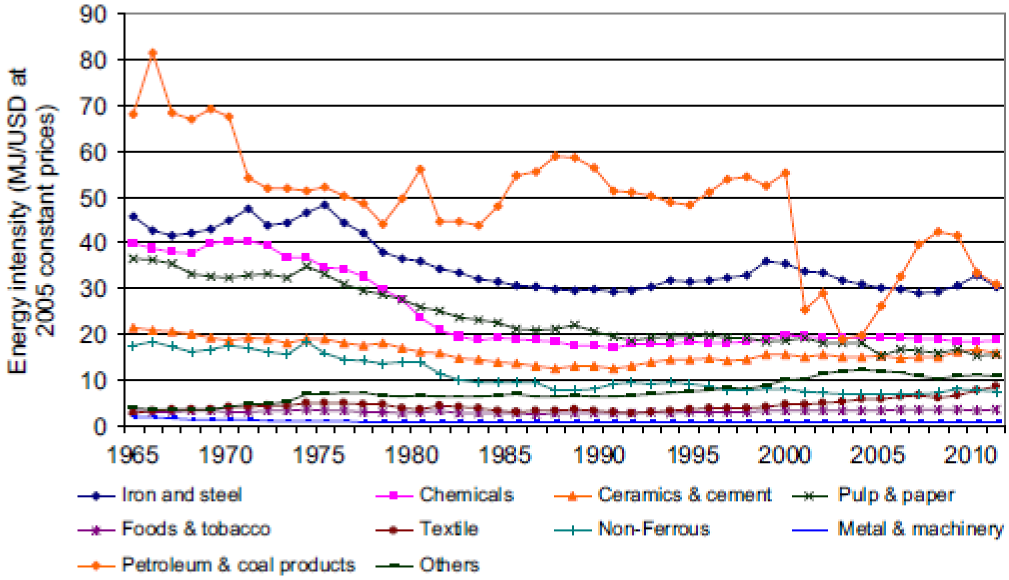


Figure 2.8: Energy Intensity of sub-sectors of Japanese manufacturing industry Source: Zhao et al., 2014:52

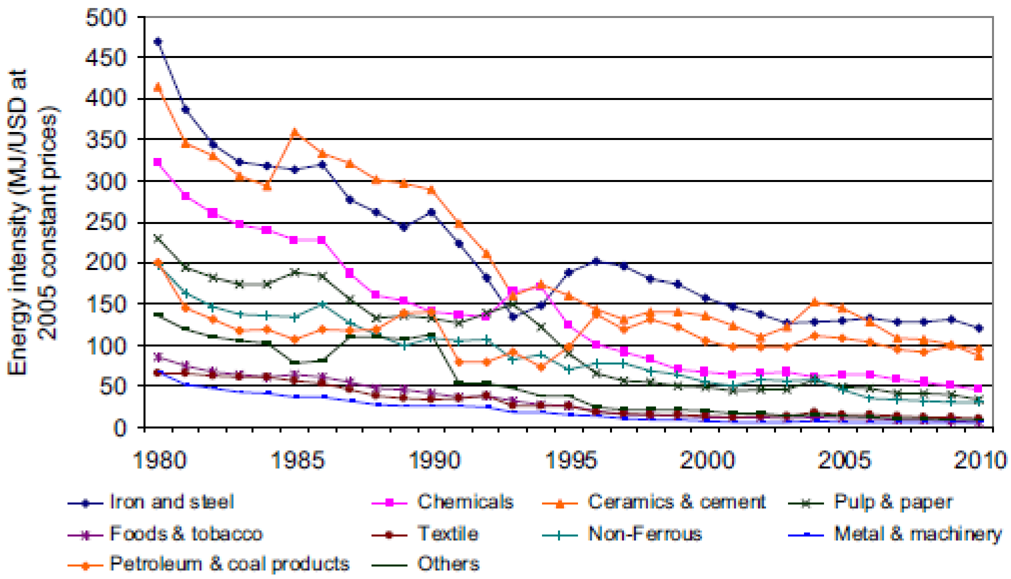


Figure 2.9: Energy Intensity of the sub-sectors of the Chinese manufacturing industry
Source: Zhao et al., 2014:52

Although the energy intensity of the Chinese manufacturing sector has significantly decreased between 1965 and 2010, the sub-sector comparisons between the two countries show that there is significant potential for energy saving in the Chinese manufacturing sub-sectors. For example, the Chinese petroleum and coal products sub-sector reached an energy intensity of approximately 100 MJ/USD in 2010 whereas the Japanese sub-sector was at approximately 30 MJ/USD, representing a 70% potential energy saving for the Chinese sub-sector (Zhao et al., 2014:52). Significant potential energy saving is also evident in other Chinese sub-sectors as depicted in the figures above.

A comparison of other Asian, US and European countries with Japan, for the period 1995 to 2013, shows that Japan is significantly ahead of many countries considered to be energy efficient, such as Germany and the UK. Figure 2.10 shows the energy intensity cross countries comparison:

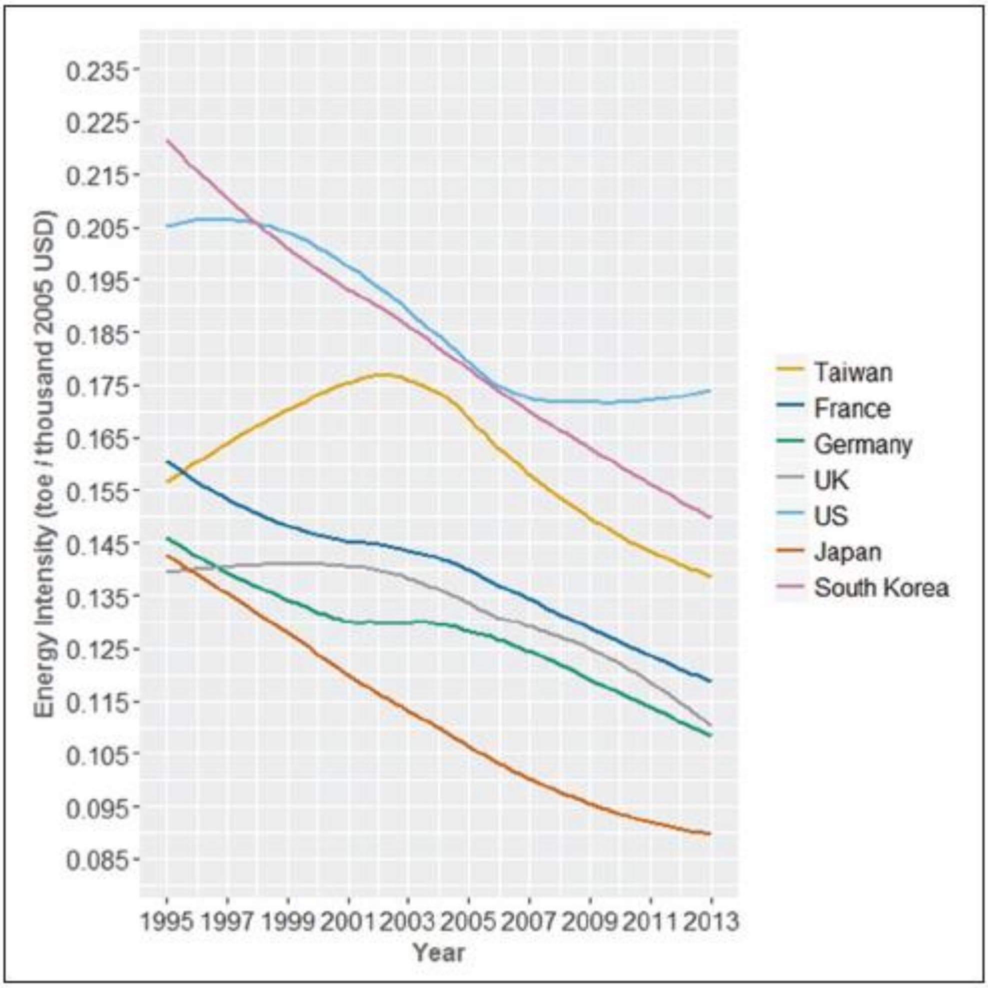


Figure 2.10: Energy intensity cross countries comparison

Source: Huang et al., 2017:30

While the potential energy saving is widespread and even prevalent in developing countries and there is an abundance of information in the energy intensive sector (namely iron and steel), there is a scarcity of information on the extent of implementable energy saving opportunities in the non-energy intensive manufacturing sector (Cagno & Trianni, 2012:2). The Industrial Assessment Centre (IAC) in the United States Department of Energy created a database of suggested energy saving opportunities for the period 1981 to 2009 (Cagno & Trianni, 2012:4). The Italian database was compared to the IAC database as it was still growing and did not adequately represent a reliable source of information in terms of evaluating energy saving opportunities (Cagno & Trianni, 2012:4). The period 2000 to 2009 was considered from the IAC database.

The most implemented energy saving opportunities (ESOs) are ranked in the IAC and Italian database (ITA) in Figure 2.11.

ARC code	Energy saving opportunity description	IAC rank	ITA rank
ISIC C25 primary metal manufacturing			
2.7142	Utilize higher efficiency lamps and/or ballasts	1	1
2.4236	Eliminate leaks in inert gas and compressed air lines/valves	2	2
2.4221	Install compressor air intakes in coolest locations	3	3
2.4133	Use most efficient type of electric motors	4	4
2.4111	Utilize energy-efficient belts and other improved mechanisms	5	5
ISIC C13 textiles manufacturing			
2.7142	Utilize higher efficiency lamps and/or ballasts	1	1
2.4236	Eliminate leaks in inert gas and compressed air lines/valves	2	2
2.4133	Use most efficient type of electric motors	3	4
2.4111	Utilize energy-efficient belts and other improved mechanisms	4	5
2.4221	Install compressor air intakes in coolest locations	5	3
ISIC C22 plastics manufacturing			
2.7142	Utilize higher efficiency lamps and/or ballasts	1	1
2.4236	Eliminate leaks in inert gas and compressed air lines/valves	2	2
2.4221	Install compressor air intakes in coolest locations	3	3
2.2511	Insulate bare equipment	4	6
2.4133	Use most efficient type of electric motors	5	5

Figure 2.11: Comparison of primary metal manufacturing, textiles manufacturing and plastics manufacturing between the IAC database and ITA database. Criterion of selection: most implemented ESOs
Source: Cagno & Trianni, 2012:5

The most implemented ESOs between the two databases are similar and mostly in the same ranking order, with slight exceptions occurring in the Textiles and Plastics manufacturing sub-sectors. An analysis was also conducted to understand the ESOs with the highest frequency of implementation, highest energy saving per annum and lowest pay-back time.

A survey of the European Manufacturing sector focusing on Slovenia and Spain identified predominant energy saving and material saving technologies employed in those countries manufacturing sectors (Pons et al., 2013:137). The results are shown in Table 2.2:

Table 2.2: Energy saving technologies and material saving technologies in the European Manufacturing Survey in 2009

Energy saving technologies (EST)	**Material saving technologies (MST)**
Control system for shut down of machines in off-peak periods	Recycled material in production
Speed regulation	Product recovery
Compressed air contracting	
Highly efficient pumps	
Low-temperature joining processes	
Energy recovery	
Bi-/Tri-generation	
Waste material for energy	

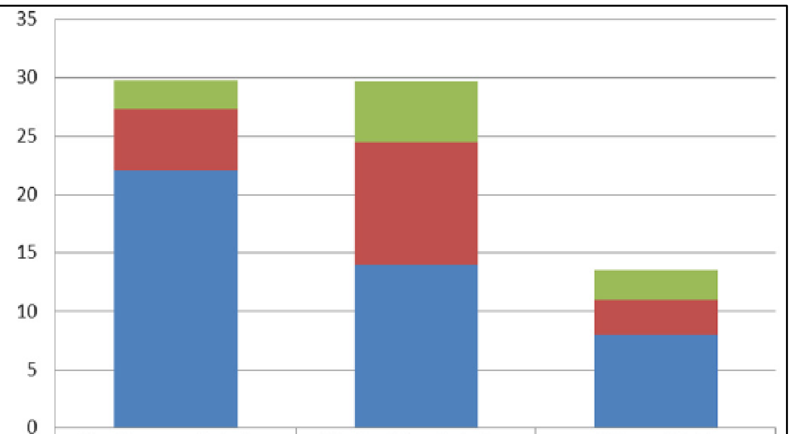
Source: Pons et al., 2013:137

The ESOs relating to lighting, elimination of leaks, and insulation did not appear in the European manufacturing survey focusing on Slovenia and Spain, while the ESOs of waste material for energy, energy recovery, Bi-/Tri-generation, low temperature joining processes did not appear in the IAC and ITA databases demonstrating potential regional or sub-sector differences in implementation of energy saving technologies.

The IAC database suggests focusing on the following three ESOs (Cagno & Trianni, 2012:6):

1. Lighting systems
2. Compressed air systems
3. Motors

The ESO relating to compressed air systems appeared to be the most profitable in terms of energy and monetary saving, as well as pay-back time. Figure 2.12 shows the ESOs annual energy saving with the shortest pay-back times per sub-sector.



	Textiles manufacturing (ISIC C13)	Plastics Manufacturing (ISIC C22)	Primary Metal Manufacturing (ISIC C25)
2.7124 - Make a practice of turning off the lights when not needed	2.42	5.2	2.5
2.6218 - Turn off equipment when not in use	5.28	10.52	3.04
2.3131 - Reschedule plant operations or reduce load to avoid peaks	22.11	13.97	7.97

Figure 2.12: ESOs on annual energy saving with the shortest pay-back times
Source: Cagno & Trianni, 2012:6

The opportunities reflected in Figure 2.12 not only represent the shortest pay-back times, but are also reflective of very small initial implementation cost. However, these ESOs require extensive involvement of production personnel, so organisational costs should be factored in (Cagno & Trianni, 2012:8).

Some of the key energy saving technologies employed in industry and their potential saving in the global industrial sector, including manufacturing, agriculture, mining and construction, have been described as follows according to (Abdelaziz et al., 2011:158-162):

- variable speed drive: an electronic power converter that generates a multi-phase, variable frequency output used to drive an induction motor and to control the motor’s speed, torque and mechanical power output. The potential energy saving for example in industrial boilers from installation of variable speed drive is estimated to range from 28 487 MWh to 115 243 MWh annually. The pay-back period is one third the life of the variable speed drive (Abdelaziz et al., 2011:158);

- energy saving through leak prevention in air compressors: leaks can waste 20-50% of a compressors output. Leak prevention can save approximately 20% of energy. Often repairing a leak requires minimal capital investment and consequently low pay-back (Abdelaziz et al., 2011:162). An example of the cost saving when preventing a leak in a chemical plant is shown in Table 2.3:

Table 2.3: Cost saving from preventing leaks in a chemical plant

Diameter of leak (in.)	Number of leaks	Cost saving ($)
1/32	100	5 765
1/16	50	11 337
1/4	10	39 967
Total		57 069

Source: Abdelaziz et al., 2011:162

- Use of high efficient electric motors. The energy saving relating to using high efficient motors depends on the power and load of the motor. The pay-back period can range from 0.7 to 7.9 years (Abdelaziz et al., 2011:161).

Figure 2.13 indicates the potential savings at different load and power levels.

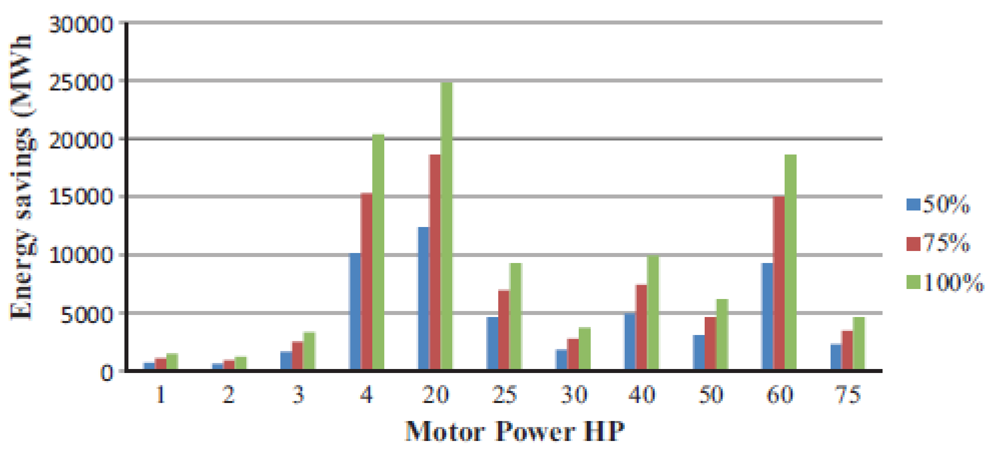


Figure 2.13: Energy savings (MWh) for high efficient motor

Source: Abdelaziz et al., 2011:160

- Energy saving realised from pressure drop – depending on the amount of pressure a system can be reduced, corresponding saving can be achieved, for example by reducing the pressure setting by 13 kPa, a 1% saving in energy can be realised in terms of compressed air electrical demand (Abdelaziz et al., 2011:163). This intervention requires minimal capital investment and associated low pay-back period;

- Energy saving from installation of Economiser – Energy saving has been estimated to be 2529 MWh annually when installed in industrial boilers and can increase the boiler efficiency up to 4%. The pay-back period is estimated to be 2.2 years (Abdelaziz et al., 2011:159-160).

The potential for energy savings can be significant and varies depending on various criteria in terms of the application such as load, power requirements, type of installation, size of equipment, etc. However, energy saving technologies are in many cases comparable per application as in the case of the US data sets and Italian database. The energy saving potentials using best available technology also vary between the industrialised or developed world and the developing world or emerging economies. For example, the potential to reduce energy consumption in the steel making sector varies between 9% in the industrialised countries to as much as 30% in developing countries (Gutowski et al., 2013:92).

Table 2.4 shows the global average direct energy intensity of production of materials and the potential energy saving from best available technologies indicating the range of potential saving between industrialised countries and developing countries.

Table 2.4: Global energy intensity and potential energy saving per sector

Sector	Primary energy intensity (MJ/kg)	Potential energy savings (range from industrialised to developing countries)
Steel	25	9-30%
Aluminium	93	12-23%
Cement	4	20-25%
Paper	23	18-28%
Plastics	32	9-27%

Source: Gutowski et al., 2013:93

Extent of energy efficiency applied in the South African manufacturing sector

The global manufacturing sector has been explored in the previous section to assess the trends in the manufacturing sector. Next the South African manufacturing sector is looked at with regards to the extent of energy efficiency applied.

In South Africa the industrial sector, being a major energy consumer, consumes approximately 35% of the total energy consumption according to (DoE, 2015a/b).

The amount of research relating to energy efficiency in the South African manufacturing or industrial sector is limited. However, there are more energy efficiency studies relating to the non-industrial sector; e.g. residential, municipalities and buildings or property.

In a comparison of international approaches to industrial energy efficiency, including the most energy consuming countries globally, South Africa scored the lowest when it came to country's performance or policy criteria related to industrial energy efficiency. The countries assessed included Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Netherlands, Poland, Russia, Saudi Arabia, South Africa, South Korea, Spain, Taiwan, Thailand, Turkey, United Kingdom and United States (Kelly, 2016:91). South Africa was one of the countries with the greatest room for improvement under the following criteria: industrial energy intensity, combined heat and power installations, policy to encourage energy management, mandate for a dedicated energy manager, energy audit requirements. South Africa only scored well in terms of establishing agreements with manufacturers and providing energy incentives (Kelly, 2016:96-98). It is important to note that this study was conducted in 2013, and South Africa's energy policy and programmes have gained some traction since then.

Targets set under the National Energy Efficiency Strategy were met and exceeded by the South African industrial sector in 2015. The results show that significant progress was made between 2000 and 2012, exceeding expectations in most sectors. For the industry sector a reduction of 34.3% was achieved exceeding the 15% target that was originally set (Republic of South Africa, 2016:1).

Moreover, in another study where the manufacturing sector in the eThekwini municipality in KwaZulu Natal has been the focus, survey results show that there has been a generally high investment of energy efficient technologies in firms in the eThekwini region; 78% of the firms surveyed responded positively to the survey conducted, where firms were asked if they had made any energy efficiency investments in their firms (Singh & Lalk, 2016:293).

The proportion of energy efficiency investments per sector in eThekwini industrial sector according to the survey is shown in Figure 2.14:

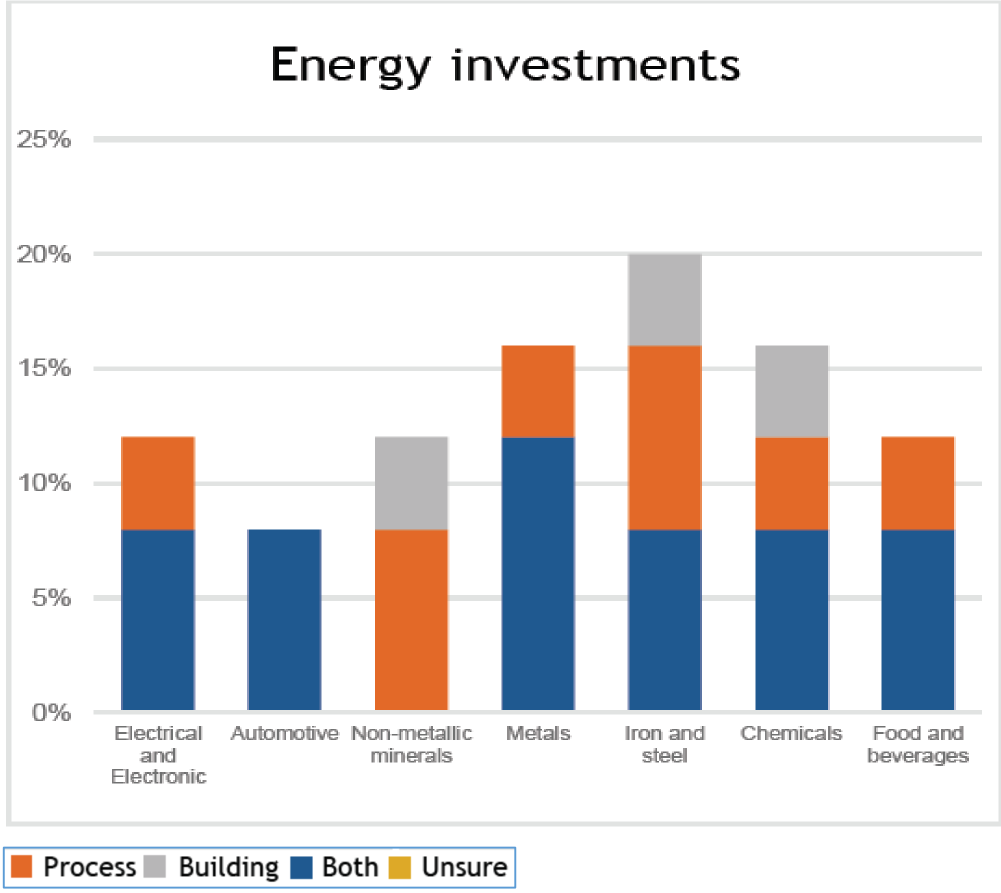


Figure 2.14: Survey results showing the investments made in process energy efficiency interventions
Source: Singh & Lalk, 2016:294

The study did not provide any insight into the potential for energy savings per sector nor the types of energy saving technologies implemented in the firms.

In comparison with the German energy efficiency policy, which is considered as high quality, or even one of the best in the world, South Africa's energy policy strategy was considered to be well thought out and compares favourably to Germany's energy efficiency policy (Mathews & Vosloo, 2015: 169).

An example of a successful energy efficiency programme in South Africa that was rolled out was the Private Sector Energy Efficiency programme launched in December 2013 by the National Business Initiative. The programme was funded through a grant from the UK Department of International Development with technical support from the Carbon Trust, a company that assists governments, organisations and companies in reducing their carbon emissions and become more resilient. Support was also received from South Africa's Department of Energy (National Business Initiative, 2015a). The programme concluded in November 2015 and supported 37 large industries across different industrial sectors in developing energy management plans (National Business Initiative, 2015a). Energy surveys were conducted at more than 900 medium company sites (National Business Initiative, 2015a).

Companies were supported towards achieving energy savings, reductions in energy-intensity, improved economic competitiveness through resource and process efficiency and implementation of projects that would result in the reduction of greenhouse gas emissions. Also, leveraging investments from the private and public sectors through capital investment in energy-efficiency projects, social benefits such as job creation and skills development relating to energy efficiency and increased awareness of energy efficiency in organisations (National Business Initiative, 2015a)

Through the Private Sector Energy Efficiency programme's energy audit a medium-sized company identified savings of at least R86,000 per year without any capital investment and another medium-sized company identified savings of at least R720,000 per annum with a once-off capital investment of R1.3 million (National Business Initiative, 2015a:10).

Figure 2.15 indicates the PSEE recommendations by technology, with average payback period in years:

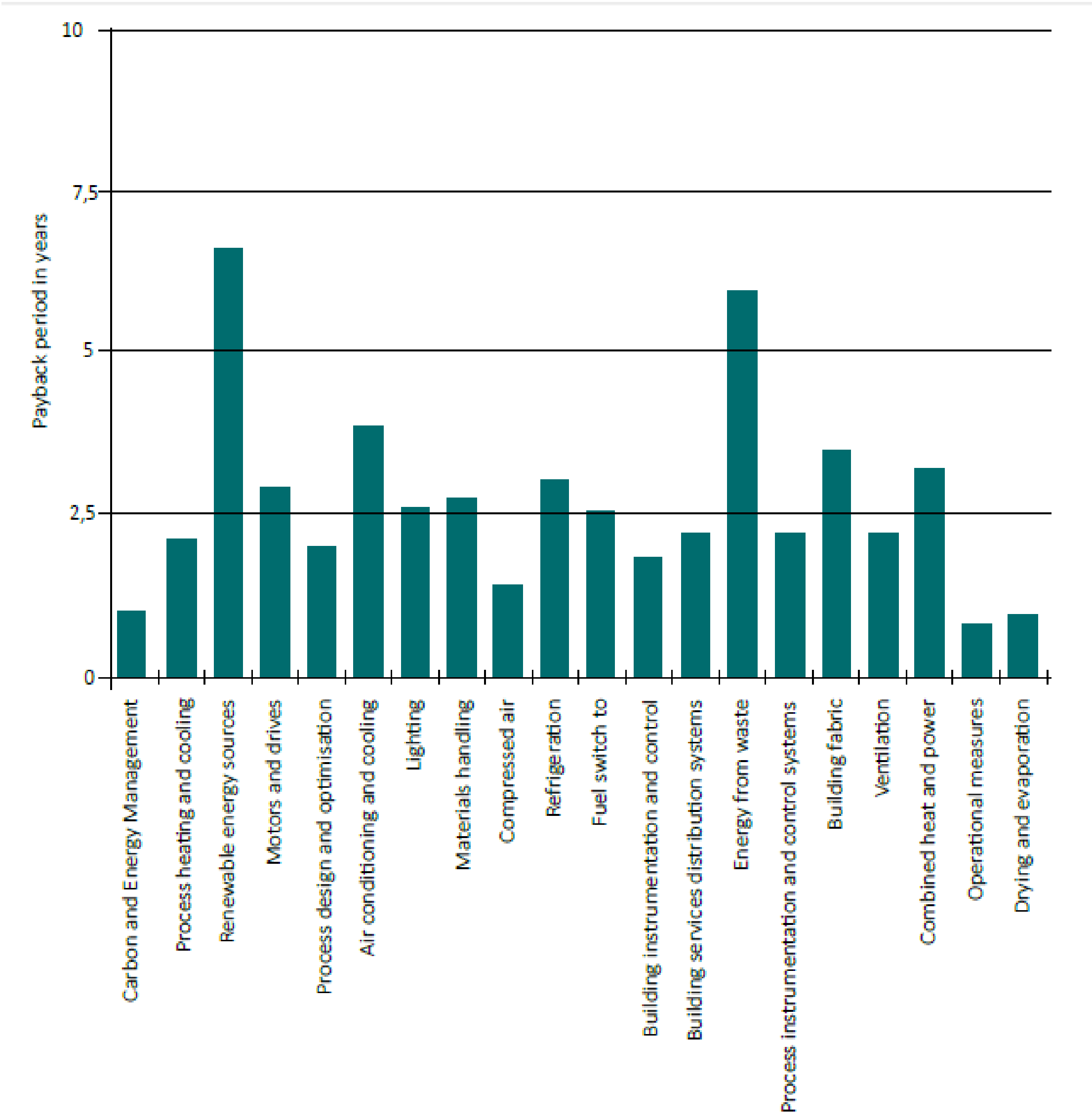


Figure 2.15: PSEE recommendations by technology, with average payback period in years

Source: National Business Initiative, 2015a:12

A number of companies have achieved significant savings (monetary and energy) by implementing energy efficiency measures (National Business Initiative, 2015a:14-15): Engen saved more than R2.3 million across its dealer network through a lighting project; Telkom saved approximately 16 million kWh since 2012 as a result of energy efficiency initiatives implemented; the installation of new technology cut Glencore's energy bills by more than 20%; Transnet is saving about R50 million annually on electricity costs by regenerating energy in new locomotives; AngloGold Ashanti recouped an efficiency investment of R6,7 million from a single project; Growthpoint's designs and retrofit energy initiatives are saving tenants more than R62 million a year; energy-efficiency projects at Woolworths are set to save the company R190 million in four years; a ventilation overhaul is saving Anglo American R2 million annually and inspiring further savings; Coleus Packaging could save more than R1,5 million annually, with first steps already saving the Johannesburg manufacturing facility R900,000 in electricity costs (National Business Initiative, 2015a:14-15).

The NBI cites some of the lessons or challenges from working with business as energy efficiency is not one of the core priorities for business – therefore there was a lack of capacity or resources that were allocated to the programme. Moreover, there was generally a lack of awareness on why energy efficiency is important to business from both an environmental improvement perspective and cost saving, there was a shortage of reliable technology suppliers that companies could access in South Africa and there is a present need for policy direction from Government especially regarding the 12L tax incentive (National Business Initaitive, 2015a:36).

The National Cleaner Production Centre of South Africa (NCPC-SA), hosted by the Council for Scientific and Industrial Research (CSIR) on behalf of the Department of Trade and Industry (DTI), is a national programme of the South African Government that promotes the implementation of resource efficiency and cleaner production methods to industry with an aim to lower costs through reduced energy, water and waste management (NCPC-SA, 2014:1). A number of projects were implemented with support from the NCPC-SA. Energy consultants were brought in to conduct energy assessments and provide training to energy managers on energy management systems and energy systems optimisation. Case studies at South African manufacturing companies are discussed below.

The NCPC-SA has rolled out several resource efficiency and cleaner production methods to industry in South Africa since 2011. Below is a summary of four energy efficiency case studies across different sectors within the manufacturing sector: chemicals, steel, pulp & paper and clothing. The four case studies are from four companies and are described below: AMKA Products Sunderland Ridge factory, Arcellor Mittal Saldanha Works, SAPPI Cape Kraft and SOCKIT Manufacturing (Pty) Ltd.

AMKA Products Sunderland Ridge factory

AMKA Products Sunderland Ridge factory was the candidate plant for a Steam System assessment by the NCPC-SA. The factory manufactures personal care and hair care products. They did not possess the required skills to improve energy efficiency, hence participation in the Industrial Energy Efficiency project was a way to obtain support in this strategic focus of the business (NCPC-SA AMKA Products, 2014:1).

Part of the programme included capacity building to key staff. Three of AMKA's employees, the Industrial Engineer, the Environmental and ISO Systems Manager and the Projects Technician, attended the Advanced Steam Systems Optimisation training through the IEE project.

The focus of the energy efficiency project was on low cost, or no cost options, i.e. low hanging fruit. This included repairing steam leaks and steam traps, excess air reduction and plant modifications, for example increased condensate recovery by installing piping, insulation of heated vessels and installation of variable speed drive on the boiler forced draft fan.

The opportunity to reduce excess air was identified due to levels in the flue gas being too high. This led to a variable speed drive being installed on the forced draft fan to allow a reduced amount of air and realising energy savings of 185,223 kWh per annum with an excellent payback of 0.17 years and minimal initial capital investment of R30,000 (NCPC-SA AMKA Products, 2014:4).

Petroleum jelly tanks were found to lack insulation. This resulted in heat losses which had to be compensated for by using additional steam. Insulation in the form of mineral wool and metallic cladding were used to insulate the tanks while also improving the appearance of the tanks. A capital investment of R150,000 was made resulting in payback of 0.51 years and energy savings of 299,533 kWh (NCPC-SA AMKA Products, 2014:4).

The third opportunity identified was recovery of condensate from the heat exchanger as the condensate was being discarded to drain resulting in a loss of water and energy. A pipeline was installed after the steam trap and linked to a common condensate return line. This resulted in all the condensate being recovered. A small investment of R2000 was made resulting in significant energy savings of 28,577 kWh and an excellent payback of 0.05 years (NCPC-SA AMKA Products, 2014:4).

The fourth opportunity identified was insulation of the Reverse Osmosis Storage Tanks, as well as recovery of condensate from the heat exchangers used to heat this water. The tanks were insulated with mineral wool insulation and metallic cladding and the heat exchanger lines were connected to a common condensate line to recover all the condensate. An initial investment of R120,000 resulted in energy savings of 439,244 kWh and a good payback of 0.26 years (NCPC-SA AMKA Products, 2014:4).

The next opportunity was to insulate the hotwell using similar insulation as the previous opportunity. This opportunity resulted in savings of 185,223 kWh with a capital investment of R80,000 realising a payback of 0.88 years (NCPC-SA AMKA Products, 2014:5).

The last opportunity involved repairing a number of steam leaks that were identified and which resulted in losses. This intervention resulted in energy savings of 299,533 kWh with a payback of 0.51 years. The capital investment was not provided (NCPC-SA AMKA Products, 2014:5).

All the initiatives implemented did not require significant capital investments but realised good savings in energy with low payback periods. In addition to the good energy savings there was a saving of 330 tonnes of CO_2 emissions per annum (NCPC-SA AMKA Products, 2014:3).

The main challenge experienced by the company was the lack of skills in the energy efficiency space to be able to identify and implement opportunities. Therefore participation in the IEE Project was an opportunity to access expert skills. There were a few process challenges, but these were overcome by finding alternative engineering solutions. A summary of the key achievements of the IEE project appear in Table 2.5.

Table 2.5: Achievements of the IEE Project

Implementation period	2014
Total number of projects	8
Monetary savings (ZAR/annum)	R 1,260,181
Energy savings (kWh/annum)	1,261,827 kWh/annum
Total investment made	R437,000
Payback time period	0.35 years
GHG emission reduction (ton CO_2)	330 tonnes CO_2/annum

Source: NCPC-SA AMKA Products, 2014:3

It is evident from the low investment made and the number of projects implemented that it is possible to realise significant savings by initially focusing on low cost projects – the company achieved a payback of only 0.35 years and significant monetary savings (approximately R1.3 million) per annum (NCPC-SA AMKA Products, 2014:3).

ArcelorMittal Saldanha Works

ArcelorMittal Saldanha Works forms part of the Steel sector in South Africa located in Saldanha Bay. Rising electricity prices together with the global and South African economic downturn have impacted on the facility's competitiveness, while its foreign competitors have not experienced the same degree of price increases. The first step was the introduction of a World Class Manufacturing programme to stabilise and increase the reliability of the operations. This phase provided a suitable platform for the Saldanha Works with which to engage with the NCPC-SA Industrial Energy Efficiency (IEE) Project which aligned with the ISO 50001 Energy Management Standard (NCPC-SA ArcelorMittal, 2013:3).

The NCPC-SA IEE Project empowered the plant engineers with the Environmental Management System (EnMS) and the Energy Systems Optimisation (ESO) expertise through a capacity building programme. This also provided ArcelorMittal Saldanha Works with internal technical and advisory support during the implementation of the EnMS, as well as various optimisation initiatives. The energy management system implemented was based on the ISO 50001 energy management system.

Some of the projects implemented in 2011 realising energy savings are: Post-combustion cooling radial fan system optimisation, Water cooling system optimisation, Ladle heating station system optimisation, Overall Low Pressure Gas (LPG) optimisation and reduction, Repair leaks and prevent wastages on Compressed Air System, Power optimisation: Power optimisers installed in main building, Increase awareness: switch off what is not required, Load shedding: utilising chemical energy during winter peak tariff, Cornac vessels: Reduce foamy slag, optimise transformer operation, Mill ancillary: switch off possible systems during standby times (NCPC-SA ArcelorMittal, 2013:6-10).
A few of the key projects are discussed below:

Post-combustion cooling radial fan system optimisation: It was identified that only one of the two fans is needed during low production periods, unplanned production stops that exceed 2 hours and during scheduled maintenance inspections. The implementation of the fans optimisation did not require any capital investment (zero payback) and resulted in energy saving of 622,000 kWh per annum (NCPC-SA ArcelorMittal, 2013:7).

A very key low cost investment project was the liquified petroleum gas (LPG) optimisation and reduction. This project realised the most significant saving from the project with no capital cost investment by mainly raising awareness and giving attention to behavioural changes and adjustment of the plant's operating philosophy. In addition a hole was identified and repaired resulting in greater availability of directly reduced gas instead of LPG. The interventions resulted in a significant energy saving of approximately 62 GWh and substantial cost savings of R52 million per annum. In addition there were CO_2 emissions reduction of 14.9 million kg (NCPC-SA ArcelorMittal, 2013:9).

Another low cost optimisation project that realised significant saving was increasing awareness by switching off what was not required. This project realised 31.7 GWh in energy saving per annum and R13.3 million rands in saving per annum with zero payback (NCPC-SA ArcelorMittal, 2013:10).

Some of the early challenges experienced was that process optimisation was done in isolation at the plant. Moreover, there was no coordination between various sections and there was no overall energy strategy in place. The National Cleaner Production Centre's IEE project supported Arcelor Mittal Saldanha Works in analysing its energy consumption in a holistic manner and upskilling the engineers to be technically capacitated in terms of energy management system and energy system optimisation. A summary of the key achievements of the IEE project are demonstrated in Table 2.6:

Table 2.6: ArcelorMittal Saldanha Works Plant Energy Efficiency Achievements in 2011

Total no. of projects	12
Total investment	R 500,000
Gross financial savings for 2011	R 89,699,000
Overall payback period (years)	0.01
Energy savings for 2011 (GWh)	80
GHG emission reduction (tons CO_2)	77,222

Source: NCPC-SA ArcelorMittal, 2013:3

As shown in Table 2.6, by making a minimal capital investment of R500,000, the company was able to offset the initial capital investment in less than four production days, translating to not only a significant energy savings of 80 GW but also R89.7 million in savings for 2011 alone. It is therefore evident that by using an energy management system as well as energy system optimisation measures, can be most effective from a cost saving and environmental perspective. In addition, many of the projects linked to creating awareness and a change in behaviour, which surprised the Arcelor Mittal team in terms of the significant saving realised. The company also reported that the initiative had provided a sustainable business model to enhance competitiveness of the business (NCPC-SA ArcelorMittal, 2013:11). This case was the best performing energy efficiency project in terms of saving and payback of all the NCPC-SA case studies reviewed.

SAPPI Cape Kraft

SAPPI Cape Kraft participated in the NCPC-SA IEE's training component to implement an Energy Management System (EnMS). The plant is a paper mill based in Montagu Gardens, Cape Town. Subsequent to the introduction of the EnMS candidate programme to the plant, the energy team at SAPPI embarked on a programme of identifying low cost energy saving opportunities.

The following projects were identified through the EnMS project (NCPC-SA SAPPI Cape Kraft Case Study, 2013:3):

- Switch off the Frotapulper when making certain grades of paper;
- Switch off the Top Line Refiner when making certain grades of paper;
- Switch off the Rewinder in the Paper Machine when not required;
- Switch off the Cameron Winder in the Coater Plant when not required;
- Implement a steam trap maintenance programme.

The key achievements relating to the implementation of the above five projects are shown in Table 2.7:

Table 2.7: Key energy efficiency achievements

Implementation period	2012-2013
Total number of projects	5
Monetary savings in ZAR	R894,000 p.a

Energy savings in KWh	3,436 GJ (944,445 kWh) – Electricity 1946 GJ (540,533 kWh) - Steam
Total investment made	R70,000
Payback time period	2 months
GHG emission reduction	1,416 tons per annum

Source: NCPC-SA SAPPI Cape Kraft Case Study, 2013:3

SOCKIT Manufacturing (Pty) Ltd

SOCKIT Manufacturing (Pty) Ltd (SOCKIT) participated in the National Cleaner Production Centre's energy efficiency programme in 2012 and 2013. SOCKIT manufactures socks for international brands and is based in Cape Town. The company employs only about 50 people and therefore found it difficult to justify a maintenance position responsible for energy efficiency and services of the plant. After attending a one day awareness workshop, the managing director of the company realised that there was a significant opportunity for energy saving in the operation.

The National Cleaner Production Centre was then brought in to conduct an energy audit which resulted in five energy optimisation recommendations being made: fuel switch, steam system optimisation, fixing compressed air leaks, compressor intake and vacuum system optimisation. Three recommendations were implemented after feasibility assessments were done internally which resulted in 92 MWh energy saving per annum (NCPC-SA SOCKIT Manufacturing, 2014:1).

The first project implemented was a fuel switch for the boiler. The electrode boilers were replaced with a liquid fuel water tube boiler. In addition the distribution system was optimised as there were often power trips due to the electrical demand often breaching the supply. This optimisation resulted in seven additional knitting machines being purchased leading to a 15% increase in production and annual electricity saving of R50,000 (NCPC-SA SOCKIT Manufacturing, 2014:2).

The second energy efficiency project was the steam system optimisation identified due to losses in steam and condensate distribution losses amounting to approximately 20% of input energy. The solution was to optimise the steam system through effective insulation, repairing leaks and installing a new condensate tank. The result of the optimisation was reduced energy distribution losses and an optimal increase in the boiler feed water temperature to over 90^{o}C (NCPC-SA SOCKIT Manufacturing, 2014:2).

The third energy efficiency project was the compressed air optimisation project which was addressed due to the compressor being unable to meet the desired set point. In addition the leakage rate was about 60% of the system design and the compressor was reaching extremely high temperatures. A decision was taken to install a new variable speed air compressor which was able to realise the required set point resulting in reduced electrical energy required and the desired leakage rate due to lower pressure. Many of the leaks were due to malfunctioning solenoid valves on the knitting machines – these valves were also replaced. The saving realised was approximately 72000 kWh per annum (NCPC-SA SOCKIT Manufacturing, 2014:2).

The total energy saving was about 92,000 kWh per annum, 30% reduction electrical energy demand, 15% increase in production demand, realising R140,000 in saving per annum with a payback of four years. In addition 4 people were employed at the company. A summary of the savings is shown in Table 2.8:

Table 2.8: Summary of savings

Implementation period	2012-2013
Total number of projects	3
Monetary savings in ZAR	R140,000 p.a
Energy savings in KWh	92 000 kWh p.a
Total investment made	R 550,000
Payback time period	4 years
GHG emission reduction	90 tons CO_2 per annum

Source: NCPC-SA SOCKIT Manufacturing, 2014:1

The company also cited some of their challenges and lessons learned. A major challenge was limited metering and difficulty in doing proper measurement and verification due to estimations on electricity bills instead of actual consumption (NCPC-SA SOCKIT Manufacturing, 2014:2).

A key challenge from many of the abovementioned case studies was the lack of skilled resources to drive optimisation projects and implement energy management systems. Only once the projects showed good results, was there adequate motivation to continue with additional projects. Many of the companies start with low cost or no cost projects and in some cases management was pleasantly surprised by the results. This is because environmental related projects typically do not result in cost saving making it very difficult to put forward a business case to senior management. It is evident from the low payback period of mostly less than 1 year that companies are driven to approve projects with the least cost and highest returns. It is, however, pleasing that the low cost projects have realised good energy saving and environmental improvements.

The next section focuses on key components of energy efficiency used in the manufacturing sector. It starts with a discussion of energy management systems and then looks at energy efficiency key performance indicators.

2.3.2 The components of energy efficiency

Energy Management Systems

In the industrial sector three types of energy management are prominent: energy audit, energy efficiency courses and training programmes, and housekeeping (Abdelaziz et al., 2011:154-157):

- Energy management constitutes a strategic area for cost reduction in industry. Some of the benefits of an energy audit are between 20 – 30%

reduction in operating costs, improvement in the overall performance of the system, as well as profitability and productivity, reduction in pollution.

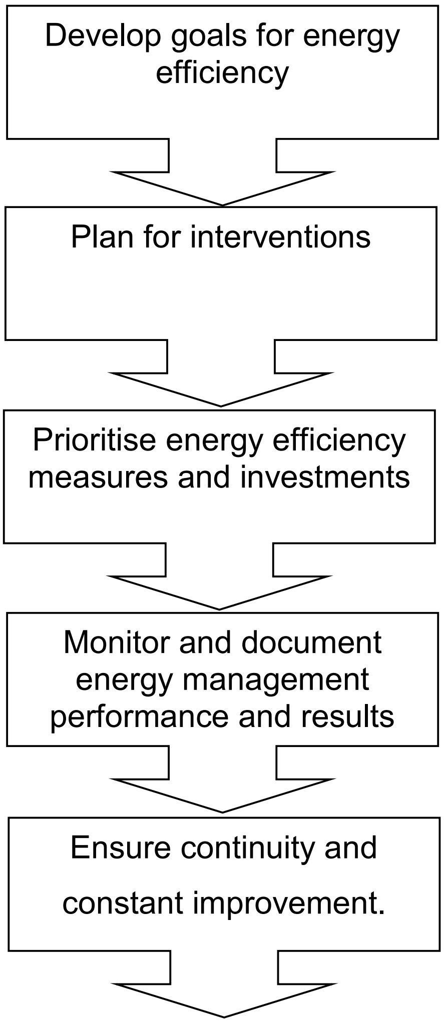
- Energy efficiency courses and training programmes are also an important way to increase the awareness of those working in the industrial sector and ultimately improving energy efficiency.
- Housekeeping is more than just cleanliness – it involves ensuring the workplace is kept in an orderly state enabling efficient processes. Some elements of housekeeping that save energy in an industrial company are: well-distributed natural lighting and good use of daylight, light coloured walls which reflect light and maintaining light fittings: lighting efficiency can be improved by 20-30% by simply cleaning lamps and reflectors.

Many industries use energy management systems to effectively manage their energy usage and identify opportunities to reduce their energy consumption. A summary of the different energy management systems employed globally is discussed below (Ngai et al., 2013:454).

The Energy Star is a well-known programme jointly developed between the U.S Environmental Protection Agency (EPA) and the U.S. Department of Energy. Energy Star promotes energy efficient products and practices, while the EPA provides a well-tested strategy for energy management with resources, tools and guidelines to assist organisations to improve energy performance.

EN 16001 is the energy management system of the European standard. It is compliant with the ISO 14001 environmental management standard and is based on the plan-do-check-act cycle. This energy management system assists organisations with setting up a comprehensive system to manage energy and thereafter continually improving their energy performance resulting in lower energy costs and reduced greenhouse gas emissions.

The ISO 50001 standard was developed by the United Nations Industrial Development Organisation (UNIDO) and the International Organisation for Standardisation (ISO) in 2008 for the integration of energy efficiency into the management practices of industrial enterprises. The ISO 50001 standard is known to be the benchmarking energy management framework for industry and organisations (Ngai et al., 2013:454). Organisations can develop the following steps based on the framework:



The State Government of Victoria in Australia developed module 4 of the Energy and Greenhouse Management Toolkit. The module outlines the following sequence of events for energy management:

- organise resources;
- appoint an energy manager and form an implementation team;
- develop a corporate energy management policy showing energy reduction targets;
- establish an energy use monitoring and reporting system;

- identify energy saving opportunities by conducting an energy audit;
- prepare an action plan after an audit based on findings;
- put in place awareness and training programmes;
- implement projects;
- report on results; and
- conduct annual reviews.

In South Africa companies use the ISO 50001 energy management standard, but are at various maturity levels in terms of implementation of the standard. Companies also use different methods to track consumption, specific consumption and targets in their organisations. Below are a few examples of models employed in South African industry:

SAPPI tracks their energy consumption for electricity and steam separately and trends their actual consumption and production on a graph to show how energy consumption relates to production. An example of this is shown in the trends in Figure 2.16 for electricity and steam consumption at the SAPPI Kraft Saldanha Mill.

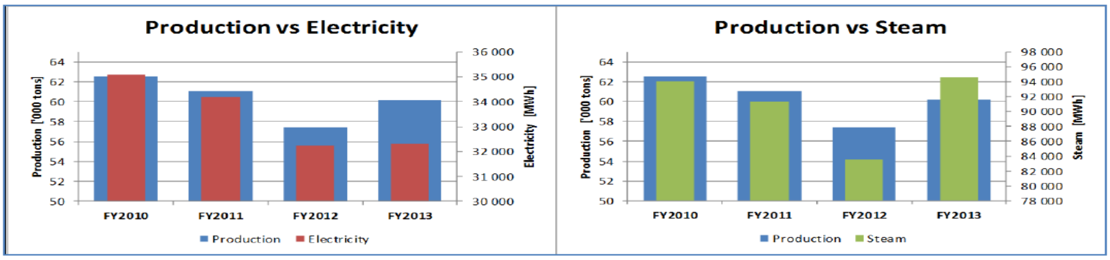


Figure 2.16: Production vs Electricity and Production vs Steam
Source: SAPPI, 2017:97

One of SAPPI's key strategic goals has been to improve energy-use efficiency. No specific targets have been set in terms of by how much SAPPI aims to reduce energy. However, energy per ton of product (energy intensity) is tracked per region in which the company operates. Interestingly, the energy intensity in the Southern African region is the highest compared to the other regions in which SAPPI operates (SAPPI, 2017:97) (See Figure 2.17).

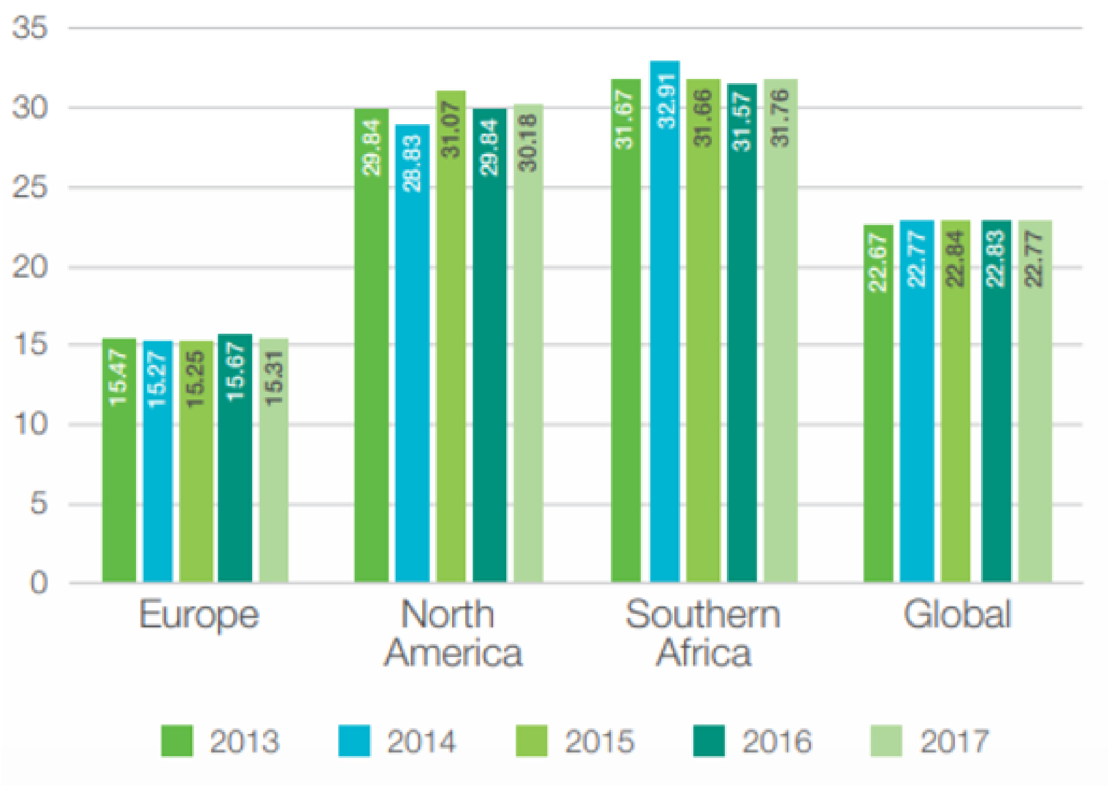


Figure 2.17: Energy intensity (GJ per air dry tonnes)

Source: SAPPI, 2017:98

SAPPI Cape Kraft uses the energy management system tool developed by UNIDO to meet SAPPI Corporate's objectives of reducing energy consumption.

The actions taken by SAPPI Cape Kraft to develop and implement an energy management system was first to develop an energy policy which was integrated into the quality management system, the roles and responsibilities were defined for the energy team, all data relevant to energy were converted to be effectively used for managing energy, significant energy users were identified and action plans developed to assess the data. Thereafter an energy assessment was conducted where opportunities were identified, which in some cases required operator intervention. Operators were trained and work procedures amended to ensure that opportunities were correctly implemented. Energy efficiency has been incorporated into the design approval process for new processes and operations and energy efficient criteria has been incorporated into procurement processes (NCPC-SA Cape Kraft Case Study, 2013:4-5).

Polyoak Packaging (Pty) Ltd (Polyoak): The company is a ‘privately owned plastic packaging manufacturer that specialises in the design and manufacture of injection and blow moulded rigid plastic packaging for the dairy, beverage, apparel, and industrial sectors in South Africa (NCPC-SA Polyoak, 2013:1).

Polyoak embarked on a programme to improve its energy usage based on rising electricity prices. A customised energy management system was implemented based on the UNIDO energy management system. The implementation of the energy management system involved undertaking the following activities (NCPC-SA Polyoak, 2013:1):

- the energy policy was signed by the Managing Director which committed Polyoak to reduce electricity consumption by 15% by December 2015;
- inclusion of documentation control procedures for energy management;
- setting of energy performance indicators: e.g. EnPI (electrical consumption divided by production);
- assessing where sub-metering would be required within the plant;
- compiling detailed electrical balance;
- identifying opportunities; and
- reporting performance.

The BMW Group South Africa implemented an energy management system in 2013. From the onset of the energy management system project, various awareness and communication campaigns were held to improve the awareness around energy management and to share success stories (NCPC-SA BMW, 2016:5).

The energy management system was rolled out using a matrix approach with roles and responsibilities clearly defined. Each section was provided with tracking information so that they could track their section’s electricity, gas and total energy performance against targets. The key indicators that were tracked were Agreed Energy %, Specific Allocation, Cumulative Allocation, MWh/unit and Cumulative MWh/unit. In addition actual performance was tracked. The performance against targets was tracked on a monthly basis (NCPC-SA BMW, 2016:6).

Some of the challenges of implementation included changing the manner of tracking energy performance from historical (forecast energy consumption) to regression based consumption (expected energy consumption) and resource and time constraints, as the resources were involved in multiple roles (NCPC-SA BMW, 2016:6).

Some highlights of implementing the energy management system was that BMW scored first on the New York Sustainability Index – the energy team was acknowledged for good energy practices and performance, and energy considerations were incorporated in design and procurement processes. One of the next steps for BMW was to seek income tax savings through the 12L Energy Efficiency Tax incentive, discussed in Section 2.6 (NCPC-SA BMW, 2016:8).

A summary of the key achievements are indicated in Table 2.9.

Table 2.9: Key achievements

Total number of projects	9
Monetary savings (Gas)	R 39,943 254
Monetary savings (Electricity)	R 8,861 054
Energy savings in GJ – Gas	278 686
Energy savings in GJ – Electricity	14 636
Total investment	R 6,577 240
Payback time period in years	0.2
CO_2 reduction(tonnes CO_2e)	19,872.7

Source: NCPC-SA BMW, 2016

A summary of the National Cleaner Production Centre energy efficiency programme in terms of the implementation of energy management systems is shown in Table 2.10.

Table 2.10: Summary of number of Energy Management Systems implemented with the National Cleaner Production Centre Energy Efficiency Programme

Project	Energy Efficiency Intervention	EnMS system
Umbilo Ethekwini Water & Sanitation	Aerator-use pattern optimisation. Reduce use of four 75kW aerators from 59h per day to 46h per day. (The aeration tank at Umbilo WWTW consumes about 83% of the total energy of the West Plant)	Implemented
Altech	Lighting: Replaced with new energy efficient light sources; compressed air: detected and repaired leaks	Not implemented
Consol Glass	Fan system optimisation project	Not implemented
Gastro Foods	Optimising steam system, compressed air pressure reduction, lighting, install efficient smoker door seals	Not implemented
Rhodes Food Groot Drakenstein	Electricity tariff, lighting, condensate return, improve boiler efficiency, conversion of steam injection system to heat exchanger, training and awareness, design and procurement process changes	Implemented
Sundays River Citrus Company	Checking and tracking energy performance	Implemented
ArcelorMittal Saldanha Works	Compressed air system, power optimisation, switch off awareness, utilising chemical energy during winter peak, reduce foamy slag, optimise transformer operation, switch off systems during standby	Implemented
Johnson Mathey South Africa	Optimise compressors and chillers, optimise production mixing vessel operating times, oven optimisation, behavioural changes, improve production efficiencies	Implemented
SAPPI Cape Kraft	Switch off Frotapulper when making certain grades of paper, Switch off Top Line Refiner when making certain grades of paper, Switch off Rewinder in the Paper Machine when not required, Switch off Cameron Winder in the Coater Plant when not required, Implement a steam trap maintenance programme	Implemented
Zimalco	Furnace retrofit and expansion, utilisation of waste heat, behavioural changes and operational control improvement	Implemented
Durbanville Hills Winery	Demand management, Chilled water plant optimisation, lighting, Compressed air system optimisation	Not implemented
Distell Adam Tas	Switch off compressors over weekends, plant optimisation, Lighting, install timers on cooling compressors	Implemented
Klein Karoo International	Control of boiler feed air, repair condensate leaks, repair steam leaks	Not implemented
Gledhow Sugar Company	Staff energy awareness and training programme, detailed survey of the steam distribution network and improvements to thermal insulation, Improvements to boiler controls, Implementation of a steam trap and steam leak maintenance programme to reduce leaks	Not implemented

Project	Energy Efficiency Intervention	EnMS system
Precision Press	Switching off electrical equipment, repairing compressed air leaks	Not implemented
Techniplate Electroplaters	Installation of temperature controller and energy meters for 42 tanks	Not implemented
Toyota SA	Occupancy sensors were placed in large offices, inefficient overhead ventilation systems were replaced with smaller localised systems, Solar water heating was installed in two ablution systems, lighting	Implemented
Feltex Automotive	Installation of small air compressor to supply weekend load, Replace resistive heater coils with infrared lamps, installation of Buffer plates, use of natural light	Not implemented
SOCKIT Manufacturing	Fuel switch, steam system optimisation, compressed air leaks	Not implemented
Toyota Boshoku SA	Replacement of existing lighting technologies with new, energy efficient technologies	Not implemented
Tenneco Automotive	Compressed air optimisation, lighting initiatives, paint shop burner submersion tube, automatic metering, new Chrome planting oven, Power factor correction, Training.	Implemented
King Shaka International Airport	Internal and external lighting initiatives, optimisation of air conditioning systems.	Implemented
Polyoak Packaging	Cooling Tower Fan and Pump optimisation, Cooling recirculation system optimisation, insulation jacket for barrel extruder, training and basic energy awareness	Implemented

Source: NCPC-SA website, Energy Efficiency case studies

As can be seen from Table 2.10 case studies that appear on the National Cleaner Production Centre's website[5], there are varying levels of adoption of energy management systems. Out of the 23 companies that participated in the Internal Energy Efficiency programme, 12 companies implemented an energy management system, mostly through funding from the United Nations International Development Organisation. Those companies that were able to implement an energy management system, cited a key challenge of a shortage of skills or resources. Another challenge was the collection of key production data due to data being collected from several locations in various different formats (NCPC-SA Distell, 2013:2). Companies that implemented energy management systems discussed lessons learnt, which included formalised training, helped with addressing people's resistance to change. However, skills for implementing energy efficiency projects are difficult to access (NCPC-SA

[5] www. http://ncpc.co.za/home-iee

Polyoak, 2013: 6). It was also shared through the case studies that support for the Energy manager is vital to ensure the continuity of the energy management system. Ownership and accountability need to filter through the organisation so that each department takes responsibility for continuous improvement in energy performance (NCPC-SA Polyoak, 2013: 6).

It is also evident from Table 2.10 that industries adopted a wide range of technologies varying from low hanging fruit (low payback) such as lighting initiatives, awareness and training, optimisation and behavioural changes to more capital intensive interventions such as fuel switching, variable speed drives, solar water systems and completely new, more energy efficient equipment.

A best practice for implementing energy management system was proposed by Javied et al. (2015:156-161). Figure 2.18 outlines the methodology to increase energy efficiency in manufacturing companies:

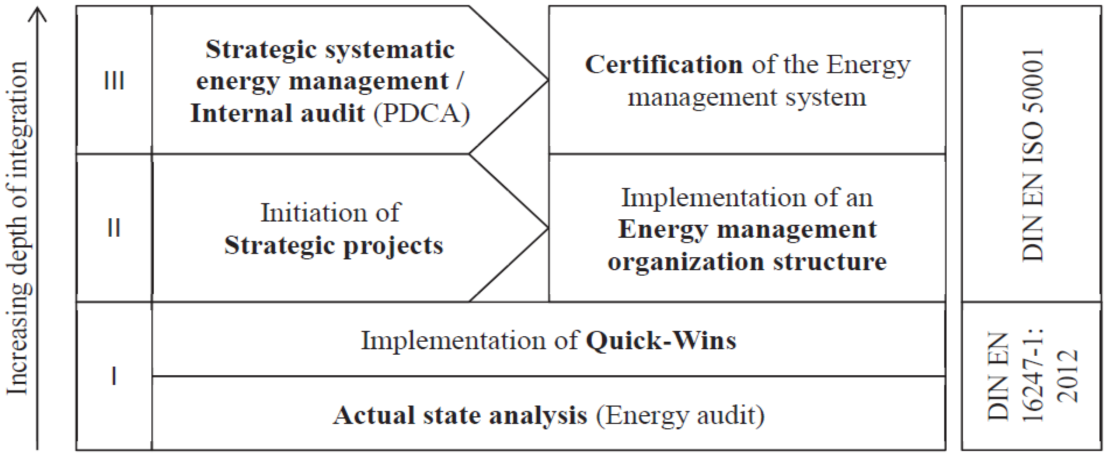


Figure 2.18: Multi-Stage model for the implementation of the energy management system.

Source: Javied et al., 2015:158

The first phase starts with an analysis of the current state by performing an energy audit in accordance with the German guideline or norm, DIN EN 16247–1:2012 that provides guidelines to alert the manufacturing company to prepare for the ISO 50001 implementation. Understanding, identifying and detecting the data using an appropriate measurement concept is key. Based on the data, energy efficiency measures can be evaluated and decisions can be made (Javied et al., 2015:158). The next phase involves implementation of quick wins whereby the company can realise benefits with little investment and minimum effort.

The next stage is then implementation of the ISO 50001 energy management system. The last step is getting certified against the ISO 50001 standard.

Data are of the utmost importance for the implementation of an energy management system. With adequately defined energy performance indicators, analysis and measures can be determined (Javied et al., 2015:160). Energy efficiency key performance indicators and targets are discussed next.

Energy efficiency key performance indicators and targets

Identifying and setting key performance indicators (KPIs) for measurement of energy efficiency is imperative in assessing performance and managing energy efficiency effectively in organisations. The famous quote by Peter Drucker, ‘What gets measured, gets managed’, holds true for many areas of environmental management, including energy management.

KPIs are used by companies to track energy efficiency measures and in the manufacturing sector have traditionally emphasized criteria related to cost, time and quality (Schmidt et al., 2016: 759).

Although there have been recent developments in measuring energy efficiency in both industry and academia, there are still ‘multiple definitions and key performance indicators (KPIs) proposed which are confusing to use and leading to the lack of broad application’ (Schmidt et al., 2016: 758).
Depending on the maturity of energy management and the level of energy, monitoring companies select KPIs best suited to their needs. Where companies wish to align energy management with policy, indicators such as absolute

energy consumption, energy intensity and thermal efficiency can be evaluated (Tanaka, 2008:2887).

In the manufacturing sector, integration of metrics in production management are key. However, there is still a need for benchmarking systems and KPIs in this sector (Bunse et al., 2011:6670). Many companies aim towards continuous improvement as one their objectives. Benchmarking KPIs for deriving improvement potentials are important, and it is recommended that process signals should be identified that are strongly correlated with the KPI for process improvements (Lindberg et al., 2015:1785).

May et al. (2015:46) aim to support companies develop energy-based performance indicators to overcome certain challenges such as benchmarking, lack of guidelines and well-developed energy management tools. A comprehensive 7-step method is proposed which is quite complex and could pose to be a barrier to implementation.

Schmidt et al (2016:759) emphasise and confirm that the effectiveness and success of application of energy efficiency KPIs depends on indicators and need to be aligned with company structures, as well as manufacturing conditions; the availability and accuracy of data are vital in order to be able to calculate KPIs on a regular basis and KPIs need to be clear and assigned to accountable individuals for reporting to higher management levels.

A methodology to develop suitable energy efficiency KPIs is proposed by Schmidt et al. (2016: 760). The methodology is depicted in Figure 2.19 using two parallel design processes:

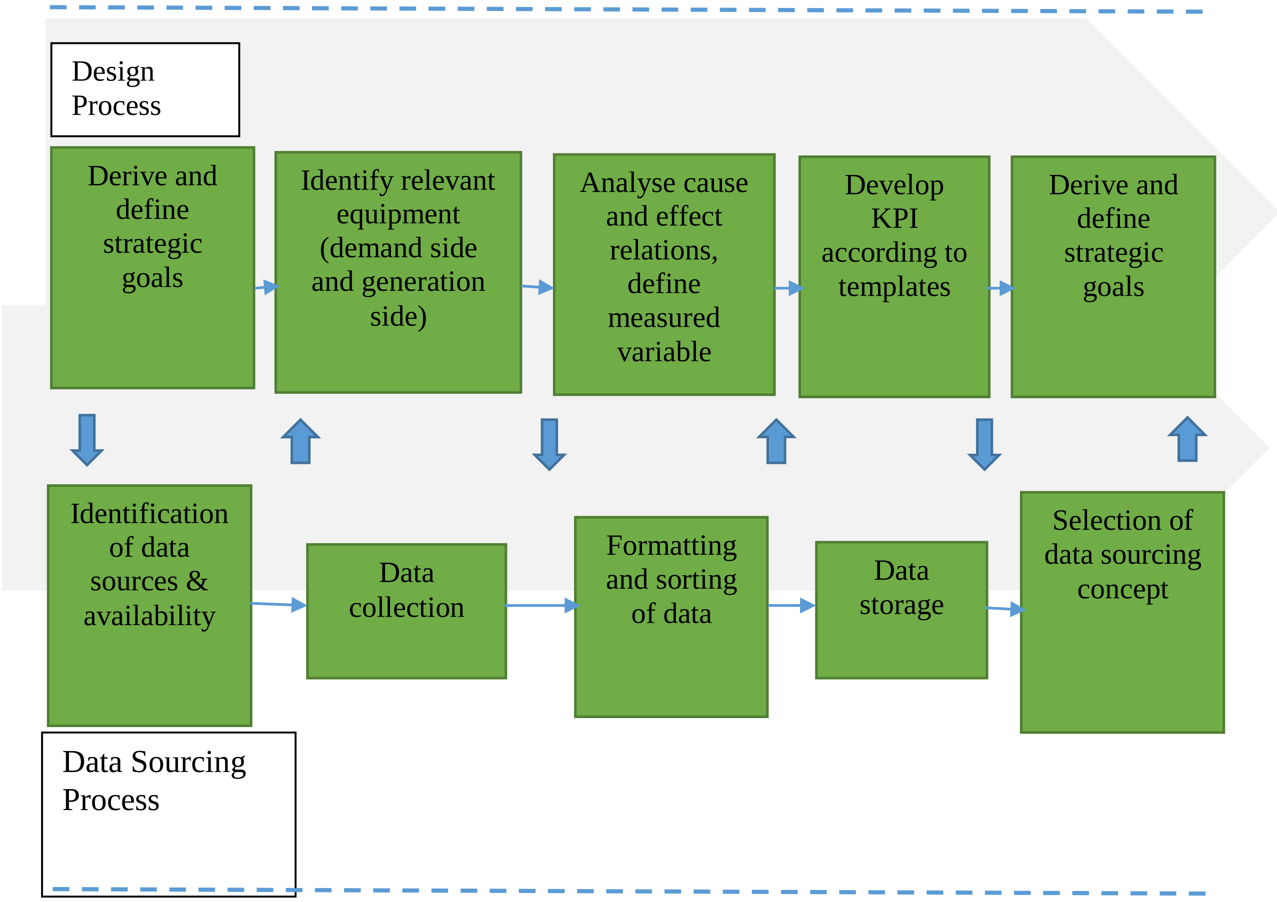


Figure 2.19: Processes for KPI development

Source: Schmidt et al., 2016: 760

The literature describes five types of KPIs according to Schmidt et al. (2016, 760). The first type of KPIs describes energy cost, consumption or share related to a specific quantity which relates to a single unit, product or machine, process line, etc. This method enables the development of various KPIs per different management levels. Type 2 KPIs can be determined by extracting information directly from the electricity bills on a monthly basis. The invoice's values only have to be added up as they are used for calculating overall energy costs at a site level and mainly designed to support senior management in running operations in a sustainable manner. Type 3 KPIs focus on the efficiency of the installed equipment. They are determined by dividing the energy output by the input energy (e.g. electricity or natural gas). The KPIs would be most applicable if measured on a daily basis. This type of KPI can be implemented at a machine level or factory level – depending on monitoring equipment – to reflect efficiencies at that level. Type 4 KPIs are of importance for operational management to determine energy savings on a daily or weekly basis in line with the manufacturing demand. They are relevant for calculating advancements from the current period to the previous period. The KPI also provides the opportunity to compare a post implementation energy usage with the baseline usage. Lastly indicator type 5 is predominantly designed for a factory and process line level to be able to align or compare the energy mixture (solar, national grid, etc.) according to internal or external influences.

The determination of KPIs, however, depends on the extent of energy meters installed on the machine level at manufacturing sites or companies. A comprehensive network of meters can enable the extension of the KPI system and result in increased energy and emissions saving due to being able to measure and address issues identified in a smaller system. According to May et al. (2015:46) industrial approaches are lacking in the development of appropriate performance indicators to compare energy consumption profiles at a machine and process level and to be able to compare energy efficiency to their competitors. May et al. (2015:58) proposes a method to develop production tailored and energy related key performance indicators at a granular level in production processes. However, there are limitations of applying such a granular method, one being the availability of energy related data in industrial practices. Many companies use the Type 2 KPIs, Schmidt et al. (2016, 760), where information is extracted from electricity bills and used to manage costs at a site level. As manufacturing sites move towards more mature energy management systems and improving energy resources, so too will come the development of more mature energy related KPIs.

A critical aspect linked to good KPIs is setting energy targets. It is becoming increasingly important in current energy policies to align the results of industries energy interventions to the efforts expressed in financial terms which is required from the target group (Rietbergen & Blok, 2010:4339).

Therefore, setting SMART targets: specific, measurable, appropriate, realistic and timed are vital. The target needs to specify clearly what needs to be achieved – specific targets should guide the target group in a direction that is preferred (Rietbergen & Blok, 2010:4341). During the duration of the period, the target must allow for constant evaluation to achieve the goal as well as effectiveness. The objective of having a measurable target is to motivate the group that is targeted so that feedback can be provided on achieving the goal. There are two aspects related to realistic targets, namely the relative distance and the costs. The relative distance addresses the effort required to achieve the goal and the cost applies to the amount of investment and the profitability and payback relating to the investment. In addition, targets should be relatively ambitious, but not too ambitious as companies or teams may have little hope of reaching the targets and will put in little or no effort in achieving them. Targets should be timed: they should ideally be set for the short to medium term. This can be a disadvantage as there may be little motivation for the company to go beyond the period. Therefore the target should be 'sufficiently ambitious in time' (Rietbergen & Blok, 2010:4341).

In addition, the development of a comprehensive set of KPIs and SMART targets are closely aligned with a robust energy efficiency programme and energy management system.

2.4. Conclusion

In addressing the first two objectives of the study, namely to assess the main drivers and barriers of energy efficiency globally and in South Africa and to identify the various components and extent of energy efficiency used in the manufacturing sector, Chapter 2 outlines the literature review firstly describing the key global and local energy efficiency drivers and barriers and thereafter outlining the global industrial practices in energy efficiency programmes.

The key drivers identified to implementing energy efficiency projects were efficiency (cost reduction), policy, energy prices, market pressure, economic development and market pressure and organisational barriers. A comparative between the drivers and barriers identified from the literature review and the drivers and barriers from AECI's Green Gauge programme is discussed in more detail in Section 6.1 of the study. The predominant driver emerging from the Literature review and the Green Gauge survey was the efficiency driver confirming that projects with good efficiency and cost savings is the key low hanging driver to accessing capital and implementing energy efficiency programmes. This finding is applicable to both developed and developing countries.

The key barriers identified in the manufacturing sector were access to capital, lack of technical skills, technological barriers, environmental management systems and behavioural awareness. Access to capital emerged as the predominant barrier from the literature review which aligned with the survey responses from AECI's Green Gauge programme (Section 6.1), inferring that an evaluation on access to capital is critical in determining whether an energy efficiency programme is undertaken.

Thereafter a focus on the South African manufacturing sector energy efficiency programmes is provided and current standards and models used in the manufacturing sector are described along with best practice energy efficiency initiatives and associated savings. The potential for energy savings across several regions and countries was found to range significantly based on the energy demand, sector and country and was therefore not comparable to the AECI Green Gauge programme. However a literature review of actual savings from energy efficiency programmes from various countries and sectors energy efficiency programmes showed comparative savings with the savings achieved from AECI's Green Gauge programme (Section 6.1.2) as well as confirming that there is a strong potential for energy savings across various sectors and countries, both developed and less developed.

The most commonly implemented energy saving opportunities were also reviewed in the literature and a comparative conducted against AECI's Green Gauge programme (pages 176-177). Energy management systems were reviewed and found that more than 50% of industries participating in the NCPC-SA programmes had implemented an energy management system. Such a system should be a strong consideration when implementing an energy efficiency programme based on the significant savings achieved from implementing systems such as the ISO 50001 energy management system.

Understanding the drivers and barriers to implementing energy efficiency projects is key in determining whether to implement an energy efficiency programme in an organisation. The extent of energy efficiency and the various components used provides a benchmark for the manufacturing sector in terms of their own energy efficiency programmes.

The next chapter outlines the energy efficiency component of AECIs Green Gauge programme as a case study of implementation of energy efficiency measures in the manufacturing sector.

Chapter 3: Case Study – The Energy Efficiency Component of AECI's Green Gauge Programme

This chapter presents the energy efficiency component of AECI's Green Gauge programme. An overview is provided of AECI's energy profile illustrating the energy mix used in the manufacturing processes. The Green Gauge Resource Efficiency (Green Gauge) programme is discussed with emphasis on the energy efficiency component. The key drivers of the Green Gauge programme are outlined. The predominant part of this chapter outlines the results of the Green Gauge energy efficiency programme implemented at 15 AECI manufacturing sites in South Africa for the period 2012 until 2015. The section covers the opportunities identified, projects implemented, saving achieved, key drivers and challenges experienced. The last section outlines the roll out of the Green Gauge programme at five key manufacturing sites representing varying maturity levels of adoption of energy efficiency interventions.

3.1. AECI's Green Gauge Programme

AECI is a South African-based company focused on providing products and services to a broad spectrum of customers in the mining, water treatment, plant and animal health, food and beverage, infrastructure and general industrial sectors. It has regional and international businesses in Africa, South East Asia, the USA and Australia. AECI was registered as a company in South Africa in 1924 and has been listed on the JSE since 1966.

The AECI Group took a significant step in 2011 with the launch of Green Gauge, which sets out measurable targets for environmental improvement. Targets were set up to 2012 and up to 2015 for individual manufacturing sites. The 2012 target was that energy audits be conducted by the end of 2012. Each of the manufacturing sites then set their own targets. Some sites, however, did not set targets. The 2011 financial year was used as a baseline.

The facilities that partook in the Green Gauge programme represented a variety of sectors within manufacturing, including mining chemicals, food, water treatment, chemicals and agrochemicals. Some sectors were prominently more energy intensive than others and presented more potential for energy savings than others. None of the sites had an individual specifically responsible for energy. In addition, none of the sites had conducted energy assessments prior to the Green Gauge programme.

Environmental consultants were contracted to assist in rolling out the programme. The first phase of Green Gauge concentrated on resource efficiency with water and energy consumption and waste generation at the forefront. This study focuses on the energy component of the Green Gauge programme.

AECI's energy make-up in its manufacturing processes includes electricity purchased for the running of motors, drives, appliances, lighting, air conditioning, geysers and combustion of various fuels, including coal, coal tar pitch, natural gas, heavy fuel oil and paraffin, to generate steam and heat.

Figure 3.1 below indicates AECIs energy mix in 2011.

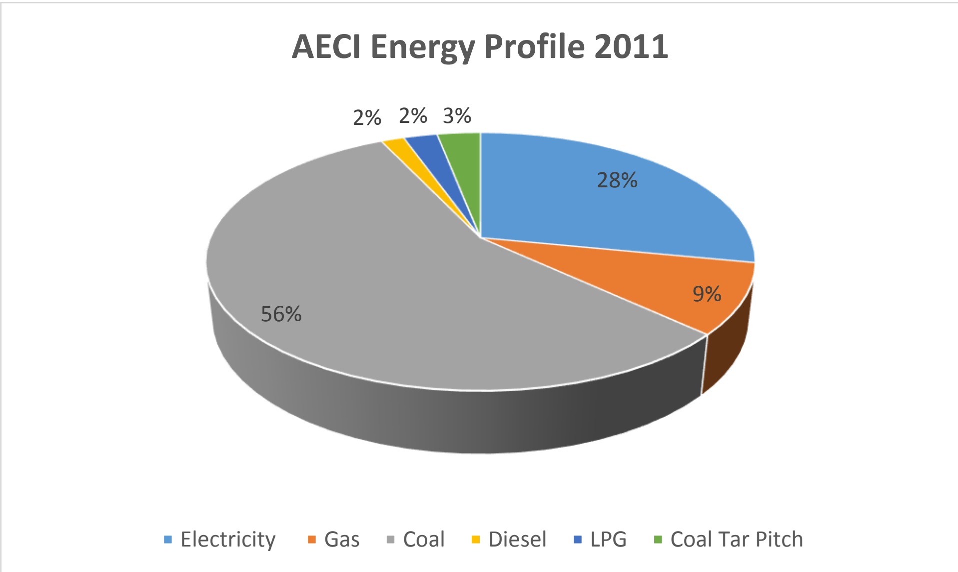


Figure 3.1: AECI's energy mix, 2011

AECI's energy consumption in 2011 was predominantly from combustion of coal in coal fired boilers at AEL Modderfontein and Acacia Operating Services. Electricity purchased from the electricity service provider made up 28% of the total energy, while gas used for combustion in steam generation made up 9% of the contribution. The remaining 7% of the energy make-up was from fuels used in smaller businesses for generation of steam and heat. The opportunity for energy efficiency interventions therefore lay predominantly in the coal combustion and electricity sphere.

The energy efficiency component involved conducting energy assessments at the 15 manufacturing sites, selecting opportunities to be implemented, setting targets per site, reporting data on a quarterly basis, monitoring and evaluation on a quarterly basis and evaluation of final data.

Figure 3.2 outlines the steps:

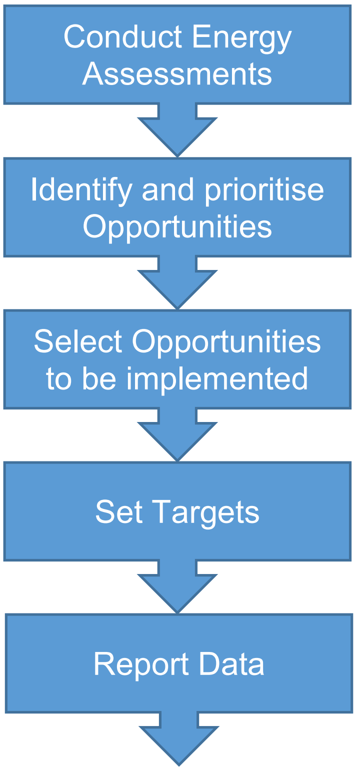


Figure 3.2: Steps towards implementing the energy efficiency component of the Green Gauge programme at AECI

Energy assessments

Specialist environmental consultants were deployed to conduct resource efficiency site assessments at AECI's 16 South African based manufacturing sites that were selected to participate in the Green Gauge programme. The assessments were concluded in 2012. Part of the resource efficiency site assessments included conducting energy assessments.

The Quick Energy Savings Technique (QUEST) was used to conduct the energy assessments. QUEST can be used to optimise energy use which can be easily integrated with existing business processes and is applicable to both large and small projects. The technique provides a holistic approach to resource efficiency addressing three key operational areas: people, equipment and data. A range of tools was used to quantify potential savings ranging from low or no-cost operational saving to large capital projects with longer payback periods.

The technique implements a continuous improvement process that is specifically designed to deliver energy, waste and water saving. It is a proven approach that has been developed over two decades and applied across a wide range of resource efficiency programmes for complex multinational manufacturers.

QUEST provides a framework of tasks and tools under each of the headings: people, equipment and data. The intention is that the energy management process is embedded into ordinary business as usual and thus QUEST will integrate seamlessly with existing quality systems, such as Six Sigma by simply extending its effectiveness to "invisible" waste such as energy.

The energy assessments were characterised by the estimations of energy saving potentials based on available data and the environmental consulting company's professional considerations.

Identify and prioritise opportunities

A detailed opportunities database, as well as a business case inclusive of net present value, opportunity cost, payback periods, potential energy and monetary savings, etc. was developed for the sites assessed. Opportunities were prioritised as follows in order to enable sites to develop management plans for implementation:

- Priority 1: Payback less than 1 year and less than R100,000 investment
- Priority 2: Payback less than 3 years and less than R1 million investment
- Priority 3: All others

The process employed at each of the sites was the following:

- Workshops – to apply internal site expertise and extract opportunities;
- Data analysis – to understand operational variability;
- Investigation of specific equipment and systems.

Three focus areas were looked at for the audit/assessment:

- First focus: understand the energy demand;
- Second focus: identify scope for saving in the utility networks;
- Third focus: assess the efficiency of equipment.

Select opportunities

After the assessment, each site was presented with an Opportunities Database in an excel spreadsheet format providing detailed information to the site to enable decisions to be made in terms of implementing opportunities. An example of key information in a site's Opportunities Database is depicted in Table 3.1:

Table 3.1: Example of key information in a manufacturing site's Opportunities Database

Opportunity Title	Basis of Calculation	Type	Capital cost (ZAR)	Electricity Savings kWh/annum	Financial Savings (ZAR/annum)	Payback (years)	Priority
Lighting sensors to turn off light during day	Assume the lights remain on 24hrs/day, 365 days/yr currently and can be reduced to 8hrs/day, as they can even be turned off	Lighting	50 000	56 064	23 273	2.15	2

time or no occupancy	when no one is there in the evenings. Cost of daylight and occupancy sensors are R1600 x 30ea x 30% installation and wiring						

Source: Internal AECI document 2011a

After the site had been provided with feedback in terms of the Opportunities Database, a team consisting of the programme manager (Safety, Health, Environmental and Quality manager or Engineer), engineers, operations manager and in some cases the Managing Director evaluated the opportunities. If feasible to the team, a capital expenditure report was prepared and submitted to senior management for approval. Once approved a budget was allocated to the project, a project plan was compiled and the project was implemented.

Set targets

After the evaluation on opportunities was conducted by the team, the programme manager set targets for energy consumption. The targets set were both absolute and specific targets based on production at the specific manufacturing facility. Targets were set up to 2015 or 2016 using a baseline, which in most cases was 2011.

The following template, Figure 3.3, was filled out by the programme manager and submitted to the researcher confirming the site’s targets for energy use.

AECI good chemistry

GreenGauge

Congratulations for successfully completing the first phase of your Green Gauge resource and waste efficiency program! By now you should have received your "assessment" phase reports and preliminary opportunity databases. We are now moving onto the second phase: Project implementation and the realisation of real operational savings. This spreadsheet document provides tools to initiate this process and consists of four steps.

Step 1. Establish Targets

Site Name:

Please advise your intended resource reduction targets by 24 August 2012, based on the outcomes of the "assessment" phase report. These should be manageable targets and account for your business projections in terms of production. The white cells need to be populated. The baseline year is 2011 and % reduction is compared each year against the same baseline data. Any improvement measures already implemented and realised can contribute towards the reduction. Note, for sites using multiple energy sources this will need to be converted to common kWh unit and combine the energy use. Please list the different energy types and respective amounts in the comments section, and the conversion basis to kWh for reference and allows cross checking for consistency in approach between each site. Additionally your baseline resource usage should be consistent with the Environmental Stats Report. However if there is an error disregard this requirement. Please liaise with ERM if you require support

	Units	Baseline (2011)	Target 2012	Target 2013	Target 2014	Target 2015	Target 2016	NB: Targets to at least 2014
Production	Tons	120	100					Notes:
Energy Use	kWh	80	75					Notes: Combine all your energy use
	% Reduction		6%	6%	6%	6%	6%	Note: if no target is entered, % reduction assumed to be maintained from the previous year
	kWh/Ton	1	0.75	0.75	0.75	0.75	0.75	
Water Use	m3	100	95					Notes:
	% Reduction		5%	5%	5%	5%	5%	Note: if no target is entered, % reduction assumed to be maintained from the previous year
	m3/Ton	0.83	0.95	0.95	0.95	0.95	0.95	
Waste	Tonnes	200	220					Notes:
	% Reduction		-10%	-10%	-10%	-10%	-10%	Note: if no target is entered, % reduction assumed to be maintained from the previous year
	m3/Ton	1.67	2.20	2.20	2.20	2.20	2.20	

Authorized By: Signature: Date:

Comments: Please list here the different energy types and respective amounts, and the conversion basis to kWh for reference and cross checking consistency between each site.
When converting steam tonnage to kWh, determine the enthalpy of the steam at the temperature and pressure it is provided to your site, and subtract the enthalpy of water at 25C (ambient). This is the basis of available latent and sensible heat energy contained within the steam.
Please cross check your baseline resource usage against the 2011 Environmental Stats Report submitted, for consistency. Where there was error identified in the stats report,

Figure 3.3: Template used to fill in targets for each manufacturing site

Source: Internal AECI Document 2011b

In addition to the above, a summary of the prioritised opportunities was completed and also submitted to the researcher. As this information could change, a quarterly submission was done. Figure 3.4 is an example of the prioritised opportunities.

AECI good chemistry

GreenGauge

Step 2. Prioritization

Please utilise the Opportunity Database provided with the Assessment Report to determine all actions you intend to take towards achieving your targets. Firstly, review the prioritization (priority 1,2 and 3) and implementation dates of the list of preliminary opportunities that were identified during the initial ERM site assessment. Feel free to adjust the project priotisation rating (i.e. you may not want to restrict Priority 1 to projects requiring less than R100,000 investment). Additionally add any new ideas from the site as time goes by. The baseline year is 2011 and any improvement measures already implemented and realised can contribute towards the reduction. The two graphs below should then update immediately and work as a management tracking tool. Please feel free to contact ERM if you have difficulty with the database.

Please summarise you priortised opportunities and initial plan for 2012 and 2013:

Op No.	Priority	Title	Estimated Capex ZAR	Actual Capex ZAR	Estimated Savings ZAR/yr	Estimated Savings Energy kWh/yr	Estimated Savings Water m3/yr	Estimated Savings Waste Tonnes/yr	Anticipated implement'n Date	Actual Implement'n Date	Status
1	1	Reduce steam pressure	-	-	39 650	65 000	-	-	Mar 2012	Apr 2012	Implemented
2	2	Example 2			5 000				Jul 2012	Aug 2012	Implemented

Figure 3.4: Prioritised opportunities template

Source: Internal AECI Document 2011c

The abovementioned information was sourced from in-house company records that included the 16 AECI manufacturing sites which participated in the Green Gauge programme. The information was submitted to the researcher on a quarterly basis for the period 2014 to 2015. As the researcher was responsible for evaluating the information as part of the Group Environmental Specialist role, this proved to be advantageous for the purpose of this study as well.

Reporting data

In addition to the abovementioned templates, a summary report (excel based) was provided to the author on a quarterly basis which included the quarterly production data in tonnes, the baseline energy consumption, the target per year and the actual quarterly performance. The information was compiled in a Green Gauge Progress report and submitted on a quarterly basis to the researcher.. The Green Gauge Progress Report shown in Figure 3.5 is a standard excel template that was developed for the purpose of the Green Gauge programme.

Figure 3.5 is an example of the quarterly progress report:

Step 4. Reporting — Year: 2015 — Site Name: Acacia Umb

Please report your progress on resource usage on a quarterly basis. This will assist management in tracking progress to achieving the targets set and the intention is to help drive implementation. Please fill in the white cells only.

	Units	Baseline (2011)	Target 2015	Qtr 1 Jan-Mar	Qtr 2 Apr-June	Qtr 3 July-Sept	Qtr 4 Oct-Dec	Acc Total	% Steam produced by coal & gas / Notes
Steam generated	Tons	155371	134824	33706	34120	37786	35191	140803	
	Coal			14783	18255	9232	10795	53065	38%
	Gas			18923	15865	28554	24396	87738	62%
CO2	tonnes	67622	23652	13876	11330	9848.42	8239.99	43294.406	Notes:
	% Reduction		65%	18%	25%	31%	36%	36%	% quarterly reduction is annualised
	tonnes/tonnes steam generated	0.435229226	0.17543	0.412	0.3321	0.261	0.234	0.307	
SO2	tonnes	309.98	100	43	52.41	26.05	17.48	138.94	Notes:
	% Reduction		68%	45%	38%	48%	55%	55%	% quarterly reduction is annualised
	tonnes/tonnes steam generated	0.001995096	0.00074	0.00128	0.00154	0.001	0.000	0.001	
RecycledWaste	Tonnes	6923	3000	1262	903	954.61	839.46	3959.07	Notes:
	% Reduction		57%	27%	37%	40%	43%	43%	% quarterly reduction is annualised
	tonnes/Ton steam	0.044557865	0.0222512	0.037	0.026	0.025	0.024	0.028	
Particulates	tonnes	1020	0.011	0.029	0.024	0.044	0.038	0.135	
	% Reduction		100%	100%	100%	100%	100%	100%	
	tonnes/tonnes	0.006564932	0.000	0.000	0.000	0.000	0.000	0.000	
Electricity	kWH	2391721	2013380	503345	433656	450019	498287	1885306.8	
	% Reduction		16%	16%	22%	23%	21%	21%	
	kWH/tonnes	15.39	14.93	14.93	12.710	11.910	14.159	13.390	

Figure 3.5: Example of Quarterly Progress Report

Source: Internal AECI Document 2011d

Figure 3.5 shows various environmental data collected by the site: CO_2 emissions, SO_2 emissions, recycled waste, particulate matter emissions and electricity consumed. For the purpose of this study, only the energy data were considered.

A description of the 15 manufacturing sites selected to participate in the Green Gauge programme is mentioned below:

Acacia Operating Services, Umbogintwini – Based in Umbogintwini, Acacia Operating Services provides services to tenants within the Umbogintwini Industrial Complex. Services provided include distribution of electricity, steam, water and effluent treatment. The production of steam was used in determining the energy efficiency. AEL Modderfontein – Manufacturer of commercial explosives and initiating systems at the Modderfontein facility in Johannesburg.

Chemical Initiatives (CI): Umbogintwini – The CI plant in Umbogintwini produces sulphuric acid, sulphur trioxide, sulphur dioxide, aluminium sulphate and plant nutrient sulphur.

Chemical Initiatives: Chamdor – The Chamdor plant, based in Krugersdorp, Gauteng, produces phosphoric acid. The plant is supported by a comprehensive infrastructure, including warehouses, bulk storage tanks, decanting and filling facilities, a QC laboratory, engineering workshop and administration.

Chemical Initiatives: Chloorkop – The Chemical Initiatives Chloorkop plant was built in 2008 and manufactures and supplies a range of specialties and locally manufactured surfactants for the Home and Personal Care Industry GGs. Manufacturing capabilities include the Sulphonation of LAB, Sulphation of Alcohol Ethoxylates and conversion of Tertiary Amines and Alkanolamides, as well as other liquid/liquid and liquid with solid blends.

ChemSystems Chloorkop – The Chloorkop facility formulates products that consumers love, including locally manufactured antifoams, emulsions, emulsifiers, waxes and formaldehyde across various industries which include personal care, homecare and pharmaceuticals.

Crest Chemicals, Midrand – The facility is a warehousing and distribution facility for a wide range of chemical products. No production occurs at the facility with the major equipment being bulk liquids storage, warehousing, a liquid product loading facility and an effluent treatment plant.

Crest Chemicals, Prospecton – Similar to its sister company, Crest Midrand, the Prospecton facility does not produce or conduct manufacturing activities. The main equipment includes bulk liquids storage, warehousing, a drum washing yard, a loading area, scrubbers and a small compressor.

Experse Flexibles, Umbogintwini – Experse Chemicals supply a range of chemicals to the manufacturing sector, including the detergent, construction, paint, mining, personal care, adhesive and agriculture industries.

Experse Urethanes, Umbogintwini – The facility produces organic chemicals, including emulsions and surfactants for a range of industries.

Improchem, Umbogintwini – Improchem provides water, energy and air solutions to customers.

Industrial Oleochemical Products, Jacobs – Based in Jacobs, Durban, IOP is primarily a manufacturer of fatty acid and rosin with capacity to convert these products into downstream products such as resins, emulsifiers and other derivatives.

Lake Foods Afoodable, Cape Town – Afoodable, based in Montagu Gardens, Cape Town, produces a range of its own unbranded products for the catering and butchery markets, as well as acting as a manufacturer and co-packer for larger local companies, including some retail outlets.

Lake Foods Infigro, Olifantsfontein – Infigro, based in Olifantsfontein, Johannesburg, supplies filter aid in Southern Africa. Infigro provides Perlite and related products to its customers.

Nulandis, Lilianton – On the Liliianton site Nulandis has production facilities that can manufacture a range of agriculture, veterinary and plant nutrition products, including insecticide, fungicides, herbicides, plant health care and animal health care products.

Senmin, Sasolburg – Senmin manufactures mining chemicals used in the beneficiation of ore in the mining sector.

The next section focuses on the key energy efficiency projects implemented and performance against targets at the 16 AECI South African manufacturing sites that were selected to partake in the Green Gauge programme.

3.2. Review of the significant energy efficiency interventions identified and implemented

Boiler conversion project of boilers at Acacia Operating Services

At Acacia Operating Services a key opportunity identified with multiple environmental and social benefits was the conversion of the coal fired boilers to natural gas firing units, not only resulting in energy savings, but also reduction in CO_2 emissions. There would be other significant potential benefits in conversion of the existing boilers from coal to gas including reduced soot and particulate emissions, reduced boiler turn down, quicker response to demand fluctuations, etc. It was understood that gas was available at a potential cost of 22 c/kWh. The project would also be advantageous to the community in that the conversion would result in a significant reduction in the number of coal trucks on the main highway (N2) that delivered coal to the site. It was recommended that a detailed study be conducted. Increasing the boiler house efficiency from the current estimated 64% to around 75 to 78% could be achieved by the gas conversion. Taking an average of 78%, efficiency would decrease kWh consumption (coal equivalent) by approximately 25 million kWh per annum although the cost of 60 R/GJ (21.6c/kWh) for gas compared to 12c/kWh for coal equivalent (depending upon coal calorific value changes) would potentially increase costs by R14 million. Despite the increase in costs by using gas instead of coal, management at Acacia went ahead with the conversion due to the multitude of benefits not only from an environmental perspective, but also the social benefits to the community. Part of the capital cost to convert the boilers was funded by the gas company as part of an agreement with Acacia Operating Services to buy a specific volume of gas from the gas company. The conversion cost of two coal fired boilers to gas fired boilers was approximately R20.5 million.

Fuel conversion of burners at Industrial Oleochemical Products

IOP commenced converting its burners from pitch to gas in 2012 and by 2015 three burners had been converted to gas. The driver for the conversion to gas was that there was a market to sell the pitch, a by-product of the process, and the revenue would off-set the capital investment and price of the gas. The capital investment for the fuel conversion project was approximately R5 million with a payback of less than 1 year.

Lighting and air conditioning

Several recommendations were made related to lighting. For example, it was recommended to replace every second light with a light emitting diode (LED) fitting which can be manually turned on to provide lighting at night for security at lower energy consumption at one of the manufacturing sites. Then during operation hours the other lights would be linked to light sensors and when lighting levels are sufficient they would turn off all the lights in the drum wash and drum fill, and half the lights in the warehouse. The estimated capital cost was R118,710 with expected savings of 136,982 kWh per annum and a payback of 1.25 years.

Another lighting opportunity was reducing electricity usage by re-wiring, installing separate switches and connecting occupancy sensors with specific zones. Thus, staff who are away from their desks or if shared space such as kitchens are empty, the lights and air conditioners will switch off automatically. The estimated capital cost for this initiative was R54,000 with expected savings of 9004 kWh per annum.

Better management of lighting and air conditioning was identified as an opportunity at 11 manufacturing sites. There were some possibilities to install day/night switches in areas where natural lighting was good such as workshop, storage, and unoccupied office areas. Efficiency of air conditioners, could also be improved, especially in areas where doors were left open and the air conditioners could be set to a higher minimum temperature. These interventions were estimated to result in potential savings of 536,043 kWh per annum with no capital investment required.

Variable speed drives

There were several opportunities identified to install variable speed drives on pump motors, air supply fans, hot water distribution systems, blowers, etc. A variable speed drive or variable frequency drive is a controller that drives an electric motor by varying the speed and voltage supplied to the motor. If equipment does not require the motor to run at full speed, the VSD can be used to ramp down the speed and voltage. The payback on variable speed drives was typically more than 2 years and many of the sites did not install VSDs due to budget constraints.

Air leaks

At many of the sites, air leaks were identified. Small air leaks were often difficult to detect in a noisy environment. Air leaks can consume up to 30% of compressor energy use. It was recommended that ultrasonic leak detectors (which can also be used to detect steam leaks and damaged steam traps) be used to detect air leaks faster. The estimated capital cost was R 3,000 for a leak detector. Potential energy savings of 717,623 kWh per annum was estimated for the sites that implemented this initiative. The payback period was on average 0.25 years. At one site compressed air leakages near the compressor house were observed which indicated that the leaks were likely along the network. It was suggested that purchasing an ultrasonic leak detector would enable the operators to closely monitor the issue and repair the leaks as part of a maintenance programme. The capital cost was the cost of the leak detector. It was estimated that the intervention would result in electricity savings of 646,617 kWh per annum and an exceptional payback of 0.06 years.

Compressors

An opportunity commonly identified at many sites was that the compressors were run at a higher pressure and any excess air was vented as a means of control. It was recommended that the sites reduce their large compressor air pressure so as to prevent venting and save energy. At one site the large compressor was found to be the largest single energy user on site. No capital cost was required to implement this intervention – the expected energy savings was, however, 59,929 kWh.

Steam condensate

The recovery or return of steam condensate was an opportunity identified at various sites. At ChemSystems in Chloorkop the steam condensate was being sent down the drain from the steam baths. Energy was lost as hot condensate was lost to the drain as opposed to being returned to the boiler. Boiler makeup water therefore needed to be heated. It was recommended that steam condensate be returned from areas such as steam baths and reactors. This opportunity was estimated at a capital cost of R100,000, with expected savings of 30,432 kWh in energy saving from gas and a payback of 1.95 years. This opportunity was implemented.

Compressed air systems

The compressed air system on the Experse Concentrates site was extensive which made maintenance difficult and costly. The compressors were not designed for the small load and low pressure requirements. It was recommended to replace the large compressors with smaller local compressors which could reduce losses and optimise the system. The capital cost was estimated at R 350,000 with expected saving of 98,384 kWh per annum and a payback of 3 years.

3.3. Review of the implementation of the energy efficiency component of the Green Gauge programme at five key manufacturing sites

This section outlines the implementation of the Green Gauge programme at five manufacturing sites. The sites were selected to be discussed based on varying levels of implementation of projects. While the energy assessments, conducted by the consultants with the assistance of operational staff, were largely successful, there were some challenges experienced. Getting the operational staff to work with the consultants was sometimes challenging as the operational staff didn't often appreciate external advice. The buy-in at a site level was sometimes lacking as site personnel did not welcome head office interventions as this was seen as being dictated to by top level management.

A description of the opportunities identified, interventions implemented and challenges experienced at five facilities.

Facility A

This facility underwent a site assessment in 2012 conducted by the consultants. The facility faced challenges relating to the sourcing of raw materials. Production is thus campaign-based and not continuous. The ramping up and down of the production process resulted in energy and water consumption that was elevated above the ideal which could be achieved during stable operations. The site has done extensive work to manage and minimise the impact of this. Given the operating conditions, the assessment focused primarily on various opportunities to minimise energy use through the installation of controls and variable speed drives (VSDs) to allow the site to modulate the plants based on demand rather than intermittently operating at full speed.

The site's energy consumption includes various energy sources: electricity, gas, pitch and heavy fuel oil. The make-up of energy consumption per energy source is shown in Figure 3.6:

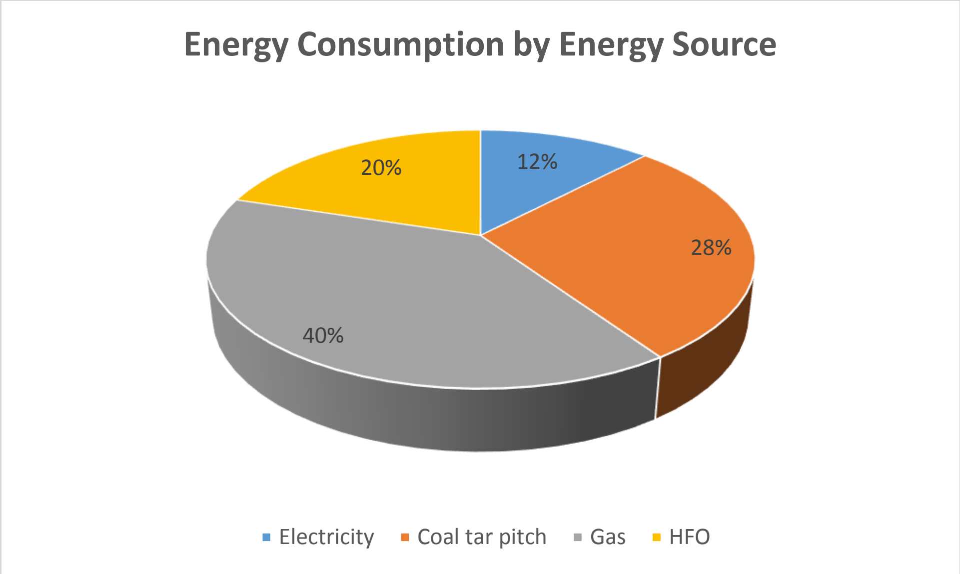


Figure 3.6: Energy consumption by energy source

Based on 2011 data energy used in burners and heaters constituted the highest energy use, approximately 88% of the total energy. Therefore the highest potential for energy saving was from the burners and heaters. The site initiated a project to convert from coal tar pitch and heavy fuel oil to gas. This project was initiated in 2011 and is detailed further below.

A summary of the opportunities relating to reducing electricity consumption, identified during the energy assessment, is described below.

It was recommended that an ultrasonic leak detector should continue to be used to target the reduction in compressed air leakage. The estimated savings was 10,000 kWh per annum.

The majority of the electricity used at the site was being used in motors and drives for the various processes and associated services. The electricity usage in motors and drives was estimated at 4 million kWh out of the total 5.2 million kWh per annum. The site had commenced a programme of replacing the ageing motors with new higher efficiency motors. No capital cost was estimated as the replacing of ageing motors would be done when required. The estimated savings was 120,000 kWh per annum.

The site employed a full time fitter to ensure that the steam distribution system was being maintained in good condition. It was recommended that this process of improvement should be continued as it was apparent that there were still a number of opportunities to reduce steam leaks either through pipe joint faults or passing steam traps. In addition, the consultants recommended that the site should consider the purchase of an ultrasonic detector combined with a thermal image camera to detect many of the steam trap faults. The estimated capital investment for an ultrasonic detector was R7,000 with estimated savings of 255,000 kWh per annum and a payback 0.06 years.

It was recommended that increased metering of key processes and equipment would focus attention on further opportunities to reduce energy usage in addition to monitoring the effect of historically implemented energy reduction projects. The estimated capital investment was R10,000 with expected savings of 26,000 kWh per annum and a payback of 0.07 years.

There were in the region of 30 split air conditioning units of which about 15 would appear to remain switched on at night and weekends in areas that are not in use. A series of local controls were installed (or existing time/temperature controls set to reflect occupation hours). In addition temperatures were set at 24°C minimum and the controller locked in a box to prevent tampering. The estimated capital investment was R20,000 with expected saving of 58,300 kWh per annum and a payback of 0.81.

The heat distribution system for steam and thermal oil is extensive and it was noted that there were some areas where valves and flanges were not fully insulated. In addition, although some insulation was in top condition there would be areas where deterioration had occurred. A detailed survey was undertaken and action taken to rectify insulation. The estimated capital investment was R200,000 with expected savings of 1.5 million kWh per annum and a payback of 0.59 years.

The consultants recommended the replacement of a large air compressor with a small unit to match load and reduce off load losses. The estimated initial capital investment was R400,000 with estimated savings of 170,000 kWh and a payback of 5.19 years.

Installation of variable speed drive on cooling water system: The cooling tower ID fans and circulation pumps were estimated to have an installed capacity of 315 kW or 220 kW allowing for a 70% loading factor. Although for maximum cooling effect full pump or fan speeds are required during the very hot summer periods, there was opportunity to reduce this load during the winter and cooler spring and autumn periods. Some of the fans were switched off during winter although this was not strictly enforced. Also it was noted that although the pumps operated at full speed the flows were throttled back. It was recommended that installing inverter drives linked to the cooling water temperature could produce a good level of savings. Only a small reduction in the running frequency could have a considerable impact on the power usage. The estimated capital investment for installation of variable speed drives on the cooling water system was R400,000 with expected savings of 324,000 kWh resulting in a payback of 2.92 years.

It was found that some trace heating applications only require heating at lower temperatures (40-50°C), e.g., to prevent solidification. It was recommended that steam condensate, which still contains considerable sensible heat, be used to heat these steams, effectively reducing the required steam flow rate. The estimated capital investment for this intervention was R150,000 with expected savings of 1,009,228 kWh and a payback of 0.29 years.

The majority of the electricity used at the site was used in motors and drives for the various processes and associated services. The electricity usage was estimated at 4 million kWh out of the total 5.2 million kWh per annum. The site had commenced with a programme of replacing the ageing motors with new higher efficiency motors. This was conducted due to noise issues raised by the older installations, but would have a consequent impact on energy usage. The estimated saving from this initiative was estimated to be 120,000 kWh. The capital investment was not estimated.

Upgrading of steam ejectors was already identified by the site before the assessment was conducted. The steam ejectors were upgraded 18 months before the assessment by the consultants – this reduced steam consumption considerably. However, this project and its historic impact on the sites energy usage was not determined and recorded.

The site implemented the following projects: Use of steam condensate for heating applications (raw material fed into the manufacturing process and to maintain temperature of bulk finished goods in storage tanks), redesign of the existing vacuum steam ejectors to allow for lower steam consumption leading to reduction in fuel usage of throughput in the continuous distillation or fractionation process, upgrade of the steam ejector system, installation of energy efficient motors on all motors rated above 75 kW, installation of variable speed drives on cooling towers and implementation of an automated system for process control, and installation of smaller air compressors. In addition a cultural or behavioural change was imposed in which reporting leaking steam and air systems was introduced which enabled these systems to be fixed timeously.

The overall performance is summarised in Table 3.2:

Table 3.2: Overall energy efficiency performance

Baseline: 2011 kWh	Baseline 2011 kWh/ton	2015 kWh	2015 kWh/ton	% reduction kWh/ton
55 849 712	2096	49 987 983	1600	24%

The site achieved an excellent performance of 24% reduction in specific energy consumption in 2015 against a 2011 baseline due to the implementation of many of the interventions recommended above. The target set by the site was initially 20% in terms of specific energy saving. The site achieved an actual energy intensity saving much higher than the amount originally envisaged. The absolute saving against a business as usual scenario was calculated to be approximately 15.5 million kWh for 2015.

Of the total energy saving approximately 90% thereof was attributed to the fuel conversion project. While the projects described above resulted in significant saving in electricity of approximately 1.6 million kWh, the majority of the saving realised was from the conversion of the burners from coal tar pitch to natural gas. This opportunity was not identified by the environmental consultants – it was identified internally and commencement of the project was in 2012, with the last burner converted in 2019. The energy saving from the fuel conversion resulted in a massive 13.9 million kWh per annum energy saving against a business as usual scenario. In addition to energy saving from the fuel conversion, there were other environmental improvements such as the improvement in atmospheric emissions which lead to a positive impact on the surrounding community.

Facility B

The energy assessment was done during 2012 and a summary of the opportunities identified are mentioned below.

The steam bath was estimated to use 454GJ of 7bar steam conservatively (20% of steam use on site) – this was based on the operators' advice of operational hours. The steam was being used to heat exchange with hot water in three baths. However, the baths were not insulated or enclosed, hence heat was continuously lost to the environment. Additionally, the baths were heated to 100°C by the steam and water was consistently evaporating (which cools the bath down). The recommendation was to install new baths with temperature control so that the temperature is varied based on the melting point of the material at the time. The new baths could be steam driven or solar hot water could be considered. The estimated capital cost was R120,000 with expected saving of 110,473 kWh per annum and a payback of 1.7 years. This opportunity was implemented.

There was noticeable cladding on the chilled water piping network which needed repair. This was identified by the site and was part of a planned upgrade by site. The estimated capital cost was R175,000 with expected saving of 3,919 kWh per annum with a payback of 58.25 years. Although the payback period was long, the capital investment was not too high and repairs needed to be done. This opportunity was implemented.

There was noticeable lagging on the steam pipe network which needed repair. In addition it was observed that there were leaks at the flanges. Regular (monthly) steam trap checking and repairs would generate significant savings. The estimated capital investment for the repair was R220,000 with expected saving of 59,795 kWh per annum and a payback of 5.75 years. This opportunity was implemented.

Compressed air systems typically consume much energy for industrial sites and sites are often unaware of how much air is often perceived as free. The compressors operate almost 24 hours to maintain the air pressure of 7bar at the site and any leaks in the system meant it needed to be made up. During the site visit it was observed that staff members were using compressed air for cleaning personal protective equipment such as clothing and safety glasses. This was a misuse of compressed air. Some compressed air leaks around the facility during the site walk-about could be heard, but specialised equipment is best to check location and extent of leaks such as ultrasonic detectors which are relatively inexpensive to purchase. It was also recommended that a regular weekly routine check be performed by site staff and the leaks subsequently repaired. The estimated capital investment was R6,000 with expected saving of 16,802 kWh per annum and a payback of 0.47 years.

Based on a rough electricity breakdown it was estimated that 23 MWh is used for office lights and air conditioning. As an example of potential saving, it was calculated that if people turned off lights and air conditioning by 20% more than currently done – for instance over lunch time and during meetings – the saving would be 4,773 kWh per annum. This intervention was implemented. The overall performance of the site is shown in Table 3.3.

Table 3.3: Overall performance of facility

Baseline: 2011 kWh	Baseline 2011 kWh/ton	2015 kWh	2015 kWh/ton	% reduction kWh/ton
1 399 168	220	1 720 705	222	1.4% increase

There was an overall increase in electricity consumption per tonne produced of 1.4% from a 2011 baseline. It was observed that of the 22 projects that were identified only 5 were implemented. The target set was 15% energy intensity saving against a 2011 baseline.

The Green Gauge programme was not beneficial for the facility although good recommendations were made by the consultants, no real effort was put into implementing the opportunities identified. Some of the challenges faced were lack of buy-in and the age of the facility and equipment. It was not easy to motivate for capital where it was extremely high as there were other important projects requiring capital. The SHEQ co-ordinator did, however, indicate that a future programme would be supported if it is better structured and driven by top management.

Facility C

The site consumes a significant amount of the Group’s electricity consumption, amounting to 16% of the AECI Group consumption based on 2011 reported data. Therefore it was vital for the site to assess its energy consumption. In terms of its energy make-up, the site’s largest energy sources were electricity, gas and steam purchased from an external source. Figure 3.7 shows the energy breakdown per energy source:

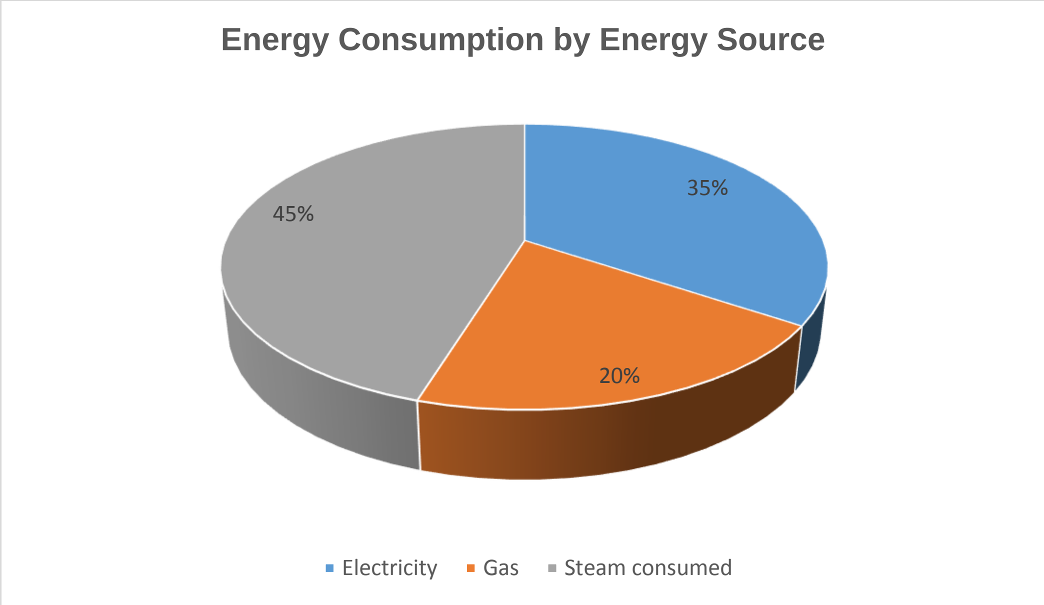


Figure 3.7: Energy consumption by energy source

While steam consumption made up the highest proportion of energy consumed, opportunities relating to steam were not feasible and the site continues to purchase steam from an external source. Electricity consumption constituted 35% of the energy consumed and the highest potential for saving was identified in electricity consumption.

The operations include multiple plants of varying ages, which produce a number of different product streams. Key energy efficiency opportunities identified during the QUEST assessment were the optimisation of cooling systems used to maintain the low temperatures needed for production processes, as well as improving condensate recovery through better deaerator pressure control.

The consultants conducted energy assessments during 2012 with a summary of the significant opportunities detailed below. It was recommended that the chiller set point be increased by reducing the pressure head across the chiller. The estimated capital investment was R0 with expected saving of 549,463 kWh per annum and a payback of 0 years. This opportunity was implemented.

The chilled water demand was found to be much lower than the chiller capacity and therefore operating at 40% load. It was recommended to convert to a variable speed drive (VSD) compressor to optimise and steady the cooling. The estimated capital investment was R800,000 with expected savings of 1,267,747 kWh per annum and a payback of 1.31 years. This opportunity was not implemented as the designer of the chiller indicated that this was not a viable option.

The existing 1000kW capacity glycol chiller serving the jacketed Xanthate reactor was required to heat 40^{0}C glycol for 5 to 6 days per week. Chillers work best under constant flow and temperature conditions. It was recommended that cold and hot glycol storage tanks be installed to buffer the flow and also to not expose the chiller to high temperatures. The estimated capital investment was R150,000 with expected savings of 886,519 kWh per annum and a payback of 0.35 years. This opportunity was implemented.

The chiller efficiency of the Chiller was 3 kW/ton, based on temperature and amperes read out from the chiller control panel. The newer chiller is 1.85kW/ton in efficiency. New chillers can achieve even better efficiencies (<1.5 kW/ton). The recommendation was to replace the 500kW Glycol Chiller with a better efficiency chiller. The estimated capital investment was R1.6m with expected saving of 2,065,669 kWh per annum and a payback of 1.61 years. A feasibility assessment was conducted and it was found that the capital cost was too high.

An opportunity to improve condensate recovery was recommended. This would result in energy saving through reduced heating of fresh top up water. In addition it would result in reduced potable water from the municipality, reduced water disposal, and reduced operating cost. Most importantly the condensate recovery project would improve deaerator operation on the CS2 plant which was over pressurised and causing condensate carry over and poor operation. This could be an operational change or may need additional capex. The estimated capital investment was R0 with expected saving of 2,010,359 kWh per annum and a payback of 0 years. At the time of the assessment, there were various problems with the CS2 condensate system and deaerator system, and the plant was not operating according to design. During the annual shutdown, several of these issues were addressed and there was a significant improvement in the amount of condensate that was being sent to effluent. The site indicated that the magnitude of the savings recommended was therefore unrealistic.

The burner was operating at 50% excess stoichiometric air, based on read outs from the computer screen in the control room and logged information by operators. It was recommended to install O_2 trim (optimisation) to tune the combustion air supply. The estimated capital investment was R160,000 with expected savings of 19,509 kWh per annum and a payback of 1.51 years. This opportunity was not implemented.

An opportunity was identified to use a steam turbine to generate electricity on site based on the steam quality, equating to 4500 kW electricity generated. The estimated capital cost was R5,628,000 with saving of 3,770,760 kWh saving and a payback of 3.1 years. This proposal was rejected, the reason provided was that generating electricity was not in line with the core business of supplying specialty chemicals to the mining industry.

Compressed air leaks have been undetected but are continuous energy losses and increase load on compressed air plant. It was recommended that a leak detection, repair and maintenance programme be put in place to improve efficiency. It was estimated that with R0 capital cost saving of 557,170 kWh per annum could be realised. This opportunity was implemented.

The site's performance was excellent and achieved excellent energy saving. The performance is summarised in Table 3.4:

Table 3.4: Overall performance of energy interventions

Baseline: 2011 kWh	**Baseline 2011 kWh/ton**	**2015 kWh**	**2015 kWh/ton**	**% reduction (kWh/ton)**
149 481 454	1429.5	98 884 507	826	42%

The site achieved 42% saving in specific energy consumption due to several projects implemented. The projects that were implemented included increasing the chiller set point, installation of glycol storage tanks to store hot glycol, improving the condensate recovery and implementation of a leak detection and repair programme. The target that was originally set was 23% saving in terms of specific energy consumption (kWh/tonne produced) and the site achieved 42% saving. Although only 4 opportunities were implemented, the implementation of the opportunities resulted in significant saving in terms of energy intensity due to opportunities with significant potential saving being selected. The absolute saving was calculated against a business as usual scenario and it was approximately 72.2 million kWh and R67.9 million for 2015.

It was indicated by the programme manager that the Green Gauge programme was beneficial in achieving energy saving as it allowed the site to identify which areas can result in saving of resources such as utilities. Some challenges experienced were the high upfront costs required and the practicality of implementation of some of the interventions recommended. The process engineer indicated she would support a similar programme in the future.

Facility D

The manufacturing facility is the largest electricity consumer in the Group and consumes about 31% of the Group's total electricity (based on 2011 data) – approximately 66 million kWh per annum. The facility is the largest energy user in the group – in 2011 the energy use was 48% of AECI's total energy consumption. Therefore the site demonstrates the largest energy efficiency improvement potential due to its high energy footprint.

The site's largest energy consumption is from combustion of coal in the boilers for generation of steam used within the facility and electricity consumption. The breakdown of energy is depicted in Figure 3.8.

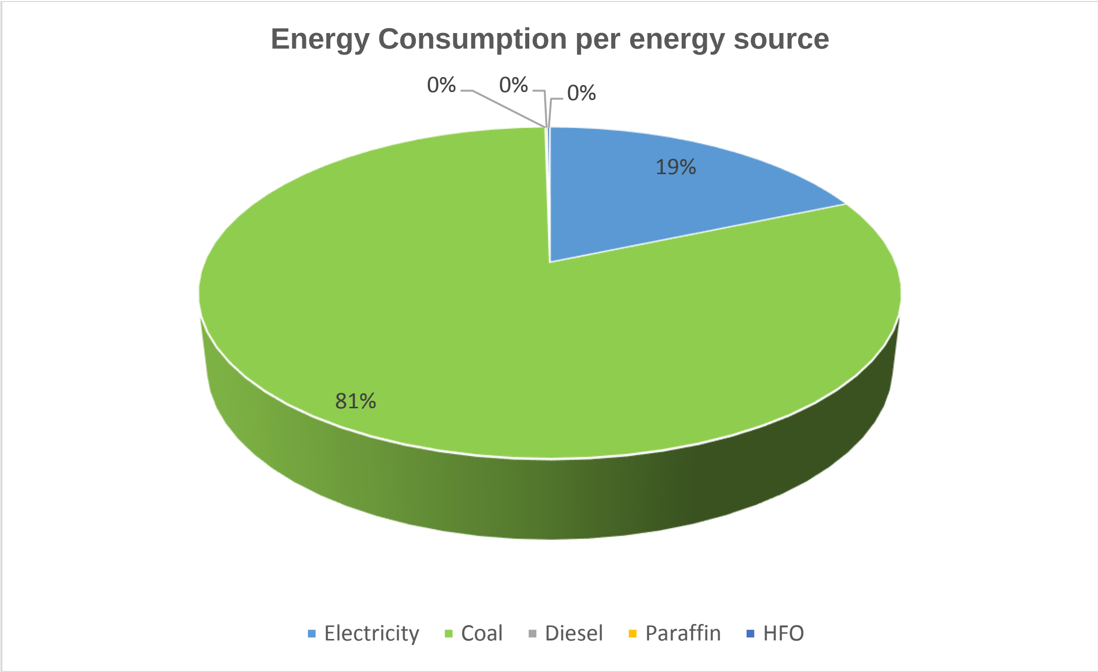


Figure 3.8: Energy consumption per energy source

Coal consumption used in the boilers to generate steam represented 81% of the total energy consumption in 2011. A project was identified by the site to use ash which had a high calorific value from historical ash dumps. However, the project was not feasible.

The largest consumer of electrical energy within the site was a plant that consumed about 12 000 MW per annum, which was approximately 25% of the total electricity consumption within the site. Focus areas to reduce electricity consumption were technical changes, installation of Variable Speed Drives on large motors, management of production variability and amending operating behaviours.

The environmental consulting company conducted an assessment at the site in 2012 and identified the following key opportunities relating to energy at the site:

One of the issues identified was that the bypass line was open to recycle excess water entering the deaerator on level control. A throttle valve was restricting flow to the deaerator and recirculating flow. The solution recommended by the consultants was to install a variable speed drive on the boiler deaerator feed pump and close the bypass. The estimated capital cost was R60,000 which would result in savings of 66,456 kWh per annum and a payback of 2.17 years.

The consultants observed compressed air leakages near the compressor house and indicated that the leaks are likely along the 12km network. They suggested purchasing an ultrasonic leak detector which would enable the operators to closely monitor the issue and repair the leaks as part of a maintenance programme. The capital cost was the cost of the leak detector which was R16,000. It was estimated that the intervention would result in electricity savings of 646,617 kWh per annum and a payback of 0.06 years.

The boiler steam is let down from 32 Bar pressure (290^{o}C superheated) to 14 Bar. The site mainly uses steam at 6 Bar or less, with only two users at high pressure. The consultants recommended that the steam turbine be installed to let down the steam to 7 Bar, with a take-off for high pressure as needed by high pressure steam users. The estimated capital cost for a steam turbine was R11 million which would realise savings of 8.3 million kWh per annum and a payback of 3.21 years.

The next finding was that there were 100 x 32W fluorescent lamps on perimeters walls or outside where there is natural light. The recommendation was to install daylight and occupancy sensors. This opportunity was used to illustrate the good payback of such sensors for the site in general. The estimated capital cost required was R50,000 which would realise savings of 56,064 kWh per annum with a payback of 2.15 years.

The Prilling plant was operational only 60% of the time so there was an opportunity to turn off the tower fans as a behavioural change. Estimated savings of approximately 42 million kWh could be realised with no capital cost.

None of the opportunities identified by the consultants were implemented by the site. The total potential energy saving from the abovementioned opportunities was approximately 51 million kWh per annum. Some of the reasons for non-implementation of projects are mentioned below based on the author's interactions with the environmental manager, as well as key personnel:

During 2014, due to resource constraints and the current business optimisation process that the business was going through, the energy projects were put on hold and needed to be reprioritised. In addition work was focused on a new boiler for the site which would potentially use ash from one of the existing historic ash dams on site. In 2015 it was found that the estimated capital expenditure for the new boiler which would also generate electricity was too high and this project was subsequently not approved.

Another reason was that the site was severely impacted by changing environmental legislation in South Africa requiring significant capital investment on reducing emissions (investment in abatement) and improving water quality for the site to be able to comply with more stringent legislative requirements such as new plant standards. This was a major blow for the site, having to retrofit equipment on a site that was more than a hundred years old.

The site therefore did not set any targets relating to reduction in energy consumption and focused its efforts on compliance. In summary, there was no capital investment allocated for energy efficiency projects between 2013 and 2015.

The Green Gauge Programme focused on waste water from the factory rather than energy efficiency projects due to compliance challenges on the Water Use Licence. The energy saving was driven from two energy surveys conducted in 2006 and 2014 by two separate consultancy firms. However, projects from these surveys were only implemented after 2016. According to the Senior Process Engineer the capital expenditure channels were normally slow in terms of approving projects.

The Green Gauge Programme was not effective in terms of the implementation of energy efficiency projects. Other key focus areas were a priority such as waste and compliance matters due to the promulgation of various environmental legislation from 2012 especially relating to atmospheric emissions and waste. The site was also focused on implementing the Clean Development Mechanism project at its Nitric Acid plants which commenced in 2008.

More recently energy efficiency projects have, however, been a focus area with a number of variable speed drive projects being implemented during 2018 and specific attention been given to the coal boiler. In addition the National Cleaner Production Centre will be conducting energy surveys during 2019 focusing on steam and compressors. As the site is more than a hundred years old, there are many improvement opportunities in terms of fixing leaks and upgrading piping systems which can achieve efficiencies. This low hanging fruit will be the focus of the assessments to be carried out by the National Cleaner Production Centre in 2019.

Facility E

The plant manufactures and supplies a range of specialty and locally manufactured surfactants into the Home and Personal Care Industries. Manufacturing capabilities include the Sulphonation of LAB, Sulphation of Alcohol Ethoxylates, and conversion of Tertiary Amines, Alkanolamides, as well as other liquid with liquid and liquid with solid blends. The facility consists of three plant areas, namely sulphonation, liquids (blending) and wax (blending), producing a range of products for the surfactant, cosmetic and detergent industries.

The environmental consulting company conducted energy assessments during 2012: a number of operational improvements were identified and investigated, including steam condensate, and a number of applications for variable speed drives were identified, including the cooling tower fans and main process blowers. The mix of energy users at the site were identified per Figure 3.9 and this was used to inform the consultants where the biggest opportunities should be focused:

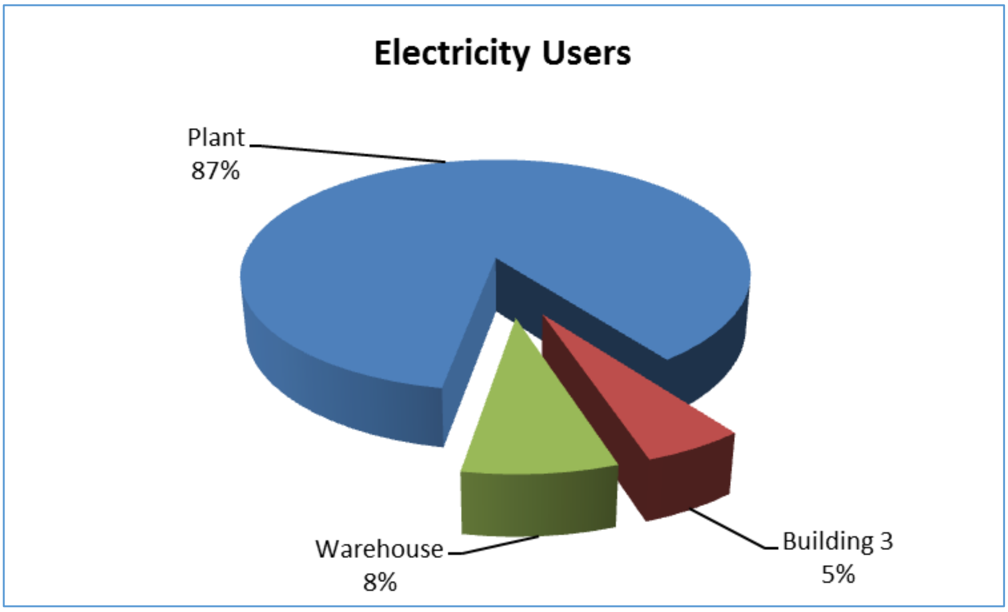


Figure 3.9: Electricity usage

The significant opportunities that were identified are summarised in detail below.

Reducing boiler steam pressure reduces the amount of energy required to raise steam in the gas boiler, reduces the operating temperature (lowering heat loss) and reduces the steam lost through leaks. The boiler pressure was set at 6 bar, but the largest steam user required 4 bar steam. Lowering the steam pressure to the required level (allowing for line losses) would reduce the fuel demand on the boiler. The estimated capital cost for this intervention was R0 with an expected saving of 389,517 kWh in energy (gas) and a pay back of 0 years. This opportunity was implemented in 2013.

Higher latent heat is acquired from steam at lower pressure. Typically temperature should be the only limiting factor when using steam for heating. As liquid plant temperature requirements are lower than 100^{0}C, the consultants recommended that steam at a lower temperature and pressure should be used. The estimated capital cost for this opportunity was R60,000 with expected energy savings of 112,495 kWh per annum and a pay back of 1.1 years. This opportunity was implemented.

Several opportunities relating to installation of variable speed drives (VSD) were identified: installation of VSDs on cooling tower ID fans, main process blowers, intercooler fan and air cooling blower. The installation of a VSD on the main process blowers was initially considered but was later rejected because of lack of costs. The opportunity is described as follows: the air/SO_3 mixture from the converter was being cooled in three air coolers powered by a fan. The air for each cooler was controlled by control valves which were maintained at approximately 20 to 30%, meaning energy was being lost against a closed valve. It was recommended that a VSD should be installed which would be able to ramp the flowrate up and down while fine tuning could be achieved with the control valves. The estimated capital cost was R141,606 with expected savings of 291,042 kWh/annum and a payback of 0.7 years.

No night time operations take place in some areas such as the warehouse, drum wash and drum filling areas. However, security was a concern. The consultants recommended replacing every second light with a light emitting diode (LED) fitting which can be manually turned on to provide lighting at night for security at lower energy consumption. Then, during operation hours the other lights would be linked to light sensors and when lighting levels are sufficient they would turn off all the lights in the drum wash and drum fill, and half the lights in the warehouse. The estimated capital cost was R118,710 with expected savings of 136,982 kWh per annum and a payback of 1.25 years. This opportunity was implemented.

Leaks are common in compressed air systems. During the site assessment it was observed that during off loading the compressed air system lost pressure very rapidly, indicating the likelihood of leaks in the system. Air leaks could typically account for up to 30% of energy use in compressed air systems. Leaks are difficult to detect manually in the high noise areas. It was recommended that an ultrasonic leak detector be purchased and used to detect air and steam leaks. The capital cost to purchase an ultrasonic leak detector was R3,000 with expected savings of 7,467 kWh per annum and a payback of 0.58 years. This opportunity was implemented in 2013.

The performance worsened in 2015 when compared to the 2011 baseline with a 26.6% increase in specific electricity consumption. The overall performance is shown in Table 3.5:

Table 3.5: Overall performance of specific electricity consumption

Baseline: 2011 kWh	Baseline 2011 kWh/ton	2015 kWh	2015 kWh/ton	% reduction kWh/ton
5 862 723	170	4,256 947	215	26.6% (increase)

According to the Safety, Health, Environmental and Quality (SHEQ) Manager the reason for the increase in energy intensity (kWh/ton production) was due to the throughput or production decreasing by 43% between 2011 and 2015 causing the energy intensity (kWh/ton) to increase as the power demand remains unchanged when production decreases due to the nature of plant equipment and the process; for example the electricity demand on the cooling tower motor does not vary with changes in production volumes.

According to feedback from the staff on site, the Green Gauge programme was beneficial in achieving energy saving as the assessment identified energy intensive equipment and compared the amount of energy the equipment should be consuming versus the amount of energy the equipment was actually consuming. Therefore, the focus was on significant energy consuming equipment. The drivers of implementing energy efficiency interventions were the energy crisis that South Africa was experiencing, alignment with AECI's values of Going Green and the ISO 14001 environmental management system requiring the facility to have an action plan in place to reduce energy, water and waste. It was relatively easy to motivate for capital for energy efficiency projects as the assessments that were conducted by the consultants were comprehensive, including calculations of initial capital investments, energy savings and payback periods. This made it easy to motivate for the projects that required significant upfront capital costs.

One of the challenges faced, at the time of the assessments, was that there was no budget allocated for the Green Gauge programme and it therefore took a long period of time to implement recommendations and this resulted in some opportunities not being implemented. Another challenge was that some managers did not have belief in the programme resulting in difficulty to motivate certain of the projects. The programme was run by the SHEQ function which had many other responsibilities, thus the Green Gauge programme did not realise its full benefit. It would have been much more effective if an individual was dedicated solely to driving the programme. Another challenge was that maintenance costs, relating to the interventions, were not factored into the costs.

Site management was, however, in full support of a similar future Green Gauge programme for the facility as it had benefited from the programme. However, resources and funding would be required for future programmes as these are typically not budgeted for which could negatively impact on the effectiveness of such programmes.

The assessment showed that there was an increase of 26.6% in the energy intensity. This was due to a significant drop in production (43% decrease) and no change in the power demand for key parts of the plant. Had there been no energy efficiency interventions implemented, there would have been a higher increase in energy intensity. However, upon assessment of the number of energy efficiency projects out of the total opportunities identified, only 5 out of the 16 opportunities identified were implemented. A more detailed assessment of the opportunities implemented versus the opportunities not implemented was conducted: the potential saving for the opportunities not implemented was approximately 2.2 million kWh, the saving from the opportunities implemented was approximately 0.93 million kWh per annum. This shows that only 30% of the potential for saving was realised.

The consultants recommended that the focus area should be gas based on the following curve indicated in Figure 3.10.

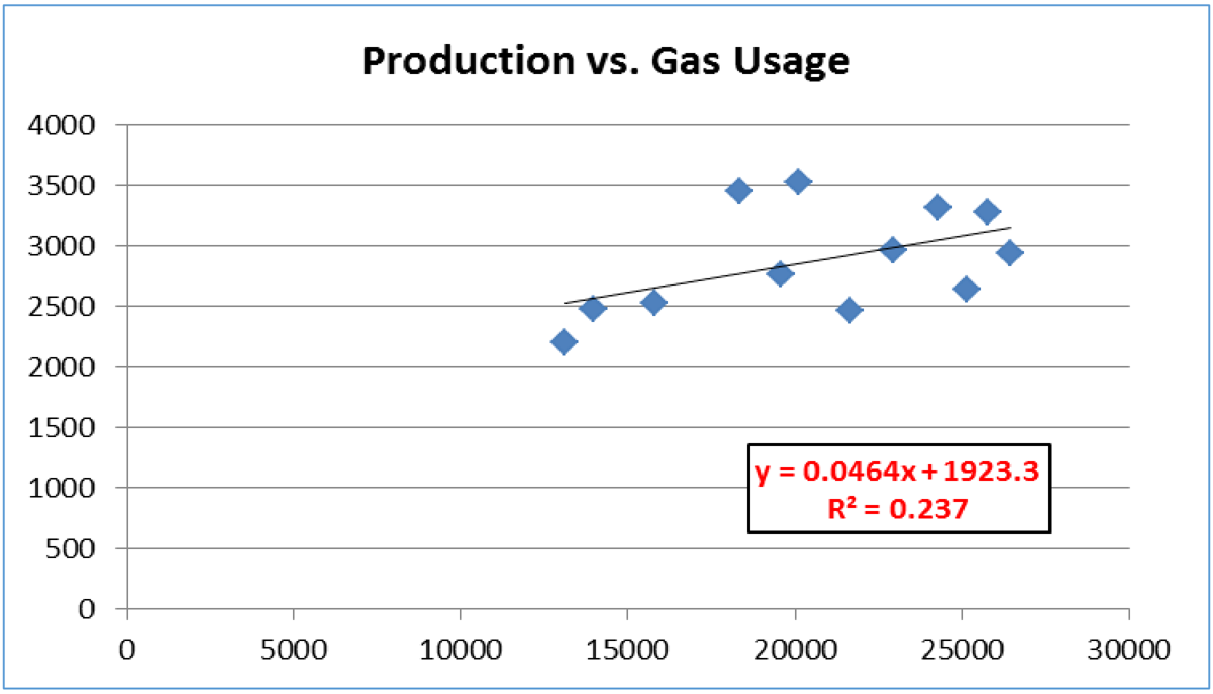


Figure 3.10: Regression curve – Production versus Gas Usage

The R^2 figure is 0.237, indicating that there is significant opportunity to optimise the gas consumption as the R^2 figure should be close to 1. It is therefore recommended that opportunities around optimising gas consumption for the site be explored going forward.

It is recommended that the opportunities that were not implemented be considered again as the potential energy savings is significant.

3.4. Summary

AECI took a bold step in 2011 to roll out the Green Gauge Resource Efficiency Programme. Some of the drivers were efficiency or cost saving, environmental performance, wastage of resources and rising energy prices.

Much effort went into the awareness and training aspects of the programme, as well as monitoring of the performance. The programme ended in 2015, but was not assessed in terms of whether it was effective in its implementation.

Manufacturing sites offer significant potential for achieving energy saving. However, based on the literature review, a small amount of saving is actually realised in industry. The results of the energy efficiency component of the Green Gauge programme are analysed in the Results section of this study and key considerations that can be applied in energy efficiency programmes in the manufacturing sector are provided.

The next section outlines the methodology for this study which is followed by the results section.

Chapter 4 – Research design and methodology

4.1. Introduction

This chapter describes the research design and methods followed to address the research objective, including the data analysis techniques and analysis, both quantitative and qualitative, used in this study. Multiple methods and tools have been used to address the research problem. This chapter first introduces the overall research design and methodology and then considers the research approach in terms of the research objectives, explaining why specific instruments were used in order to gather and analyse data.

4.2. Research design

The research design process is described as 'a framework for the collation and analysis of data' according to (Bryman & Bell, 2011). In the case of AECIs Green Gauge programme the key factors to consider in terms of constructing the research design were:

1. An in-depth literature review to respond to research objectives 1 and 2 (assessing the main drivers and barriers, and identifying the various components and assessing the extent of energy efficiency applied in the manufacturing sector).
2. The gathering methods to be used for the qualitative assessment, i.e. survey, questionnaire, interview;
3. The type of data which exists for AECI manufacturing sites that participated in the Green Gauge programme;
4. AECI did not have a mature energy management system in place, therefore a quantitative assessment alone would not necessarily provide the insight or results required to respond to the research objective 3: To evaluate the effectiveness of energy efficiency in AECI's Green Gauge Resource Efficiency Programme.

Based on the abovementioned factors the research design selected was a mixed methods research that combined quantitative and qualitative research. Taking the abovementioned factors into consideration, the research design is illustrated in Figure 4.1:

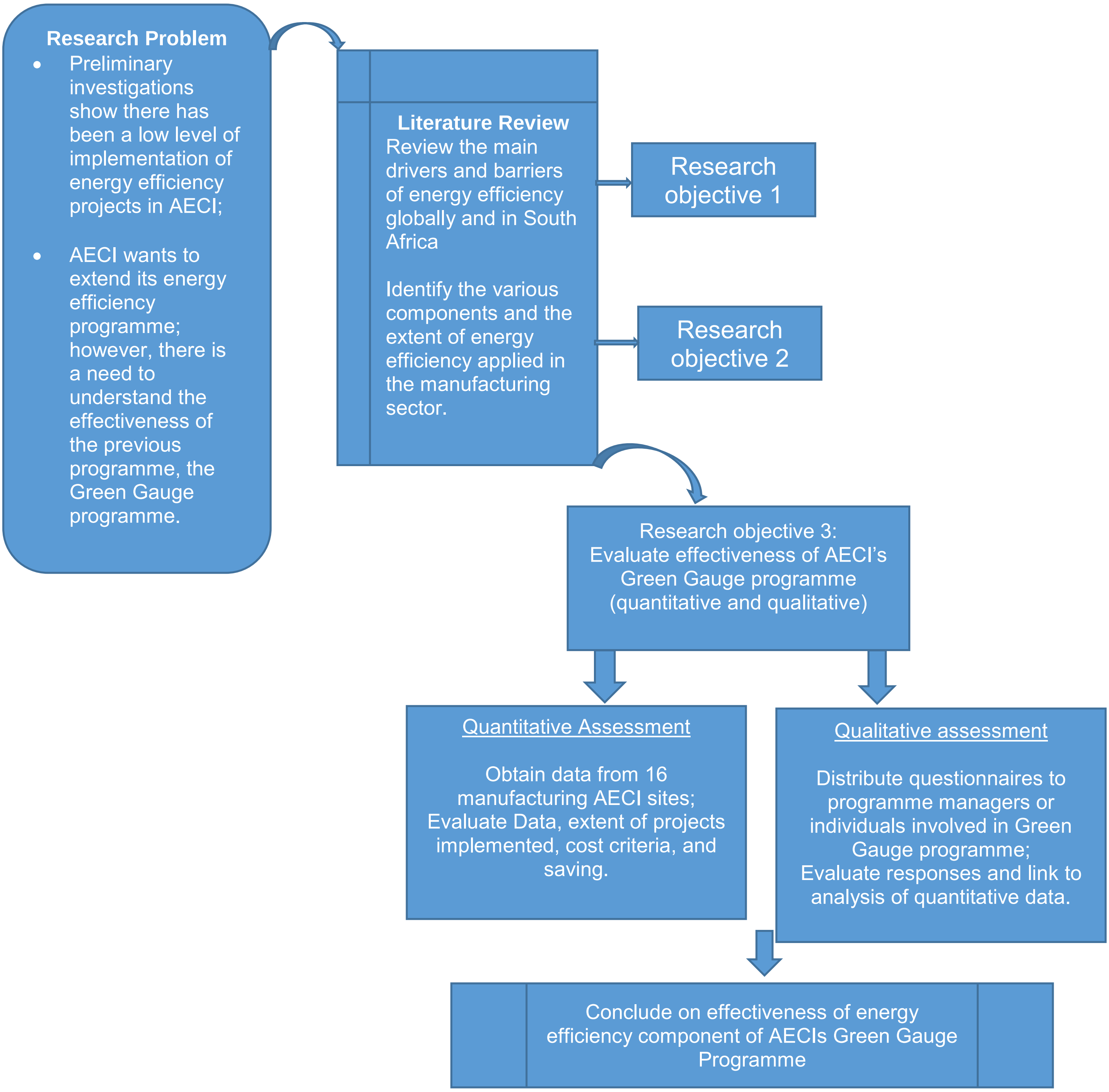


Figure 4.1: Research design

4.3. Research methodology

According to Bryman and Bell (2015, 641) 'the term *mixed methods* research is used as a simple shorthand to stand for research that integrates quantitative and qualitative research within a single project.'

Bryman and Bell (2015, 646) further explains four basic mixed methods designs:

a) The Convergent Parallel Design involves the collection of both quantitative and qualitative data each having equal priority. Thereafter the analyses are compared and combined into an integrated one.

b) The Exploratory Sequential Design involves the collecting qualitative data before collecting quantitative data. This type of design can be associated with studies where the researcher wishes to generate a hypothesis which is thereafter tested using quantitative methods.

c) The Explanatory Sequential Design method involves collecting and analysing quantitative data followed by qualitative data so that the quantitative findings can be elaborated on. The researcher may need to use such an approach when he/she feels that additional insight into the quantitative findings is needed or that the broad patterns of relationships from quantitative research require an explanation.

d) The Embedded Design can use either qualitative or quantitative research as the priority design, but also draws on the other approach to address, for example, a subsidiary research question. The need for this type of design can be due to the researcher wishing to enhance her/his research.

It is evident that both qualitative and quantitative data would be required from the research design process. The Explanatory Sequential Design Method explained above was most suited to this study due to the findings from the quantitative data requiring additional insight or explanation. A comprehensive amount of literature was reviewed to ensure that adequate insight was obtained from a global and local perspective and applied to the case study of AECI's Green Gauge programme.

The advantage in using AECI's Green Gauge programme as a case study, was that it enabled the author to access data from each manufacturing site that partook in the programme. The author was also actively involved in the monitoring phase of the programme by reviewing quarterly reports from the manufacturing sites, calculating savings relating to absolute and specific parameters and regularly engaging with the programme managers at each site regarding the implementation of projects. Through collecting data, as well as collating responses to questionnaires completed by the programme managers, the author was able to assess the effectiveness of the energy efficiency component of the Green Gauge programme using the Explanatory Sequential Design Method.

4.4. Research method

This section outlines the instruments used to collect and analyse data in terms of the research objectives. Both quantitative and qualitative data were collected.

Research objective 1: To assess the main drivers and barriers of energy efficiency in the manufacturing sector globally and in South Africa

Literature review analysis

Conducting a literature review forms part of an acknowledged approach in building the basis of a research and is vital in defining the design, objectives or methodology of the study, (May, 2017:1467). The literature review serves as an evaluation of the existing body of research knowledge in a particular field of interest and to identify gaps that may potentially exist (Tranfield et al, 2003:207).

As part of objective 1, a detailed literature review was conducted to understand the drivers and barriers of implementing energy efficiency projects both globally and locally. In addition, trends in developing countries, as well as developed countries, were considered to compare the issues experienced in South Africa.

The search process is depicted in the figures below. The first database used to conduct the search was the SCOPUS Database. The process is depicted in Figure 4.2:

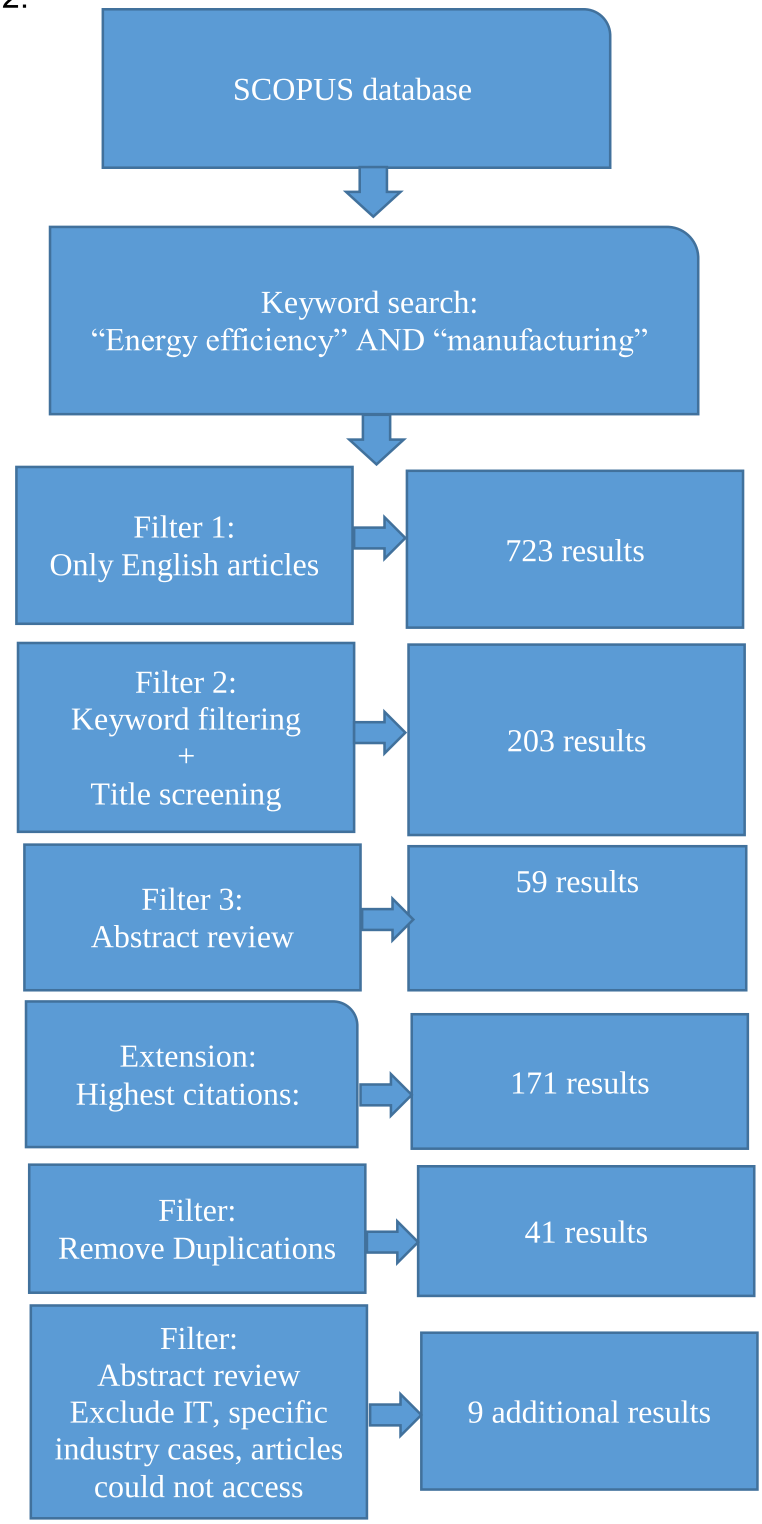


Figure 4.2: Search process using SCOPUS Database

The second database used was SABINET (South African database) to search for peer reviewed articles in the South African manufacturing landscape – see Figure 4.3.

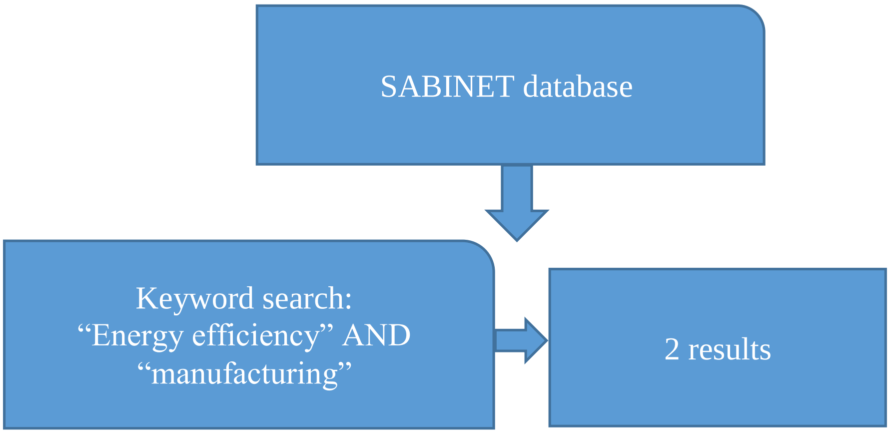


Figure 4.3: SABINET search process

The third database used was Google scholar. Figure 4.4 shows the process:

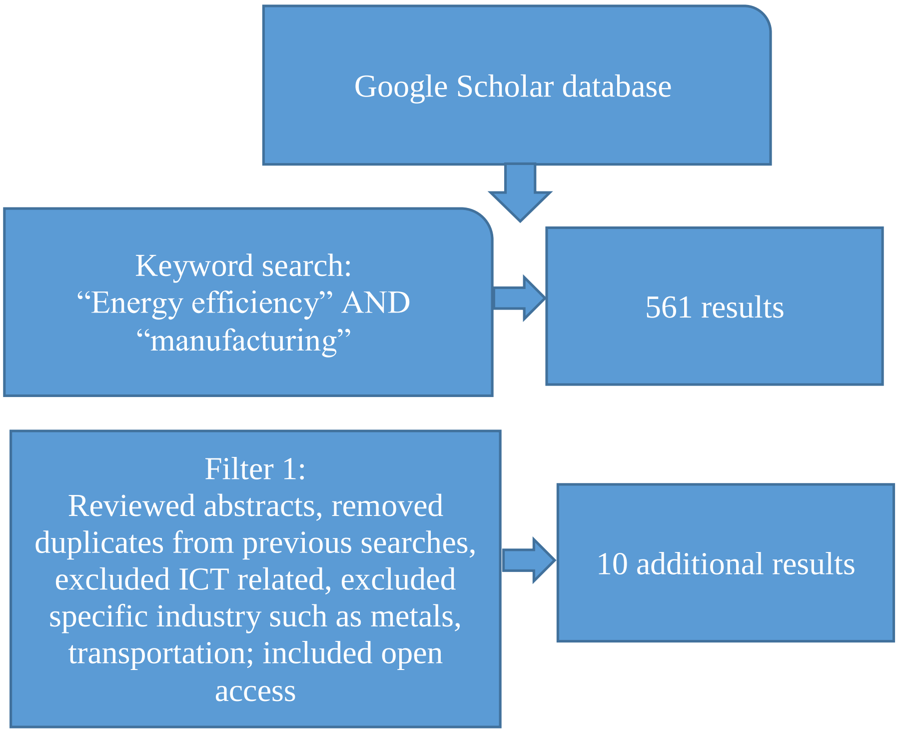
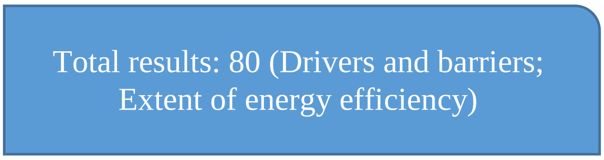


Figure 4.4: Google Scholar search process



The publications were searched on Scopus, SABINET and Google Scholar databases. The Scopus database was the first search engine used due to the availability of only peer reviewed articles in the database. It was decided to not allocate a time period to the search initially as it would be decided after the search whether there would a limit based on the relevance to a specific time period from examining the articles.

The basic keywords used for the search were "energy efficiency" and "manufacturing" and the first search performed on the Scopus database using the word AND. The search was limited to English only resulting in 723 titles. The search was also filtered for the highest cited. Then the search was constrained to article titles which yielded 203 results. It was then necessary to identify the relevant articles by doing the following:

- Reading the titles and abstracts of the articles;
- Excluding the articles referring to information technology used in energy efficiency;
- Excluding the articles referring to specific sectors such as tractors, metals, transportation, electricity generation, etc.
- Excluding articles referring to bio energy, bio fuels, solar power.

This exercise resulted in 59 results.

Next, the article with the highest number of citations was identified with 171. The duplications from the first search were then excluded by reviewing the titles resulting in 41 results. Then the following exclusions were done by reviewing the abstracts of the articles:

- Excluding the articles referring to information technology used in energy efficiency;
- Excluding the articles referring to specific sectors such as metals;
- Articles which could not be accessed.

This exercise yielded 9 results.

From the previous 2 searches it was found that there was only one result relating to South Africa. Therefore the Sabinet database was then searched for peer reviewed articles in the South African manufacturing landscape. This search yielded only 2 results.

Next Google Scholar was used to search for additional articles using the keywords “energy efficiency” AND “manufacturing” resulting in 561 results. The following process was then applied by reviewing the titles and abstracts:

- Removed duplicates from previous searches;
- Excluded the articles referring to information technology used in energy efficiency;
- Excluded specific industry such as metals, transportation;
- Included open access articles.

This resulted in 10 additional results.

The literature review was concluded when saturation was reached as all the references began leading back to the articles already identified.

In total 80 results were yielded from the searches.

In addition to the abovementioned search in terms of peer reviewed articles, the author also assessed two programmes, The National Business Initiative (NBI) Private Sector Energy Efficiency programme (PSEE) and the National Cleaner Production Centre (NCPC-SA) resource efficiency programme were reviewed.

The NBI PSEE programme was reviewed reflecting trends showing the various types of energy efficiency projects plotted against the payback period in years.

The drivers from 24 case studies from the National Cleaner Production Centre Industrial Energy Efficiency Programme was assessed to compare to what was identified from the peer reviewed articles.

Research objective 2: To identify the various components and the extent of energy efficiency applied in the manufacturing sector.

Literature review analysis

Conducting a literature review forms part of an acknowledged approach in building the basis of a research and is vital in defining the design, objectives or methodology of the study (May, 2017:1467). The literature review serves as an evaluation of the existing body of research knowledge in a particular field of interest and to identify gaps that may potentially exist (Tranfield et al., 2003:207).

As part of objective 2, a detailed literature review was conducted to identify the various components and extent of energy efficiency applied in the manufacturing sector.

The search process is depicted in the figures below. The first database used to conduct the search was the SCOPUS Database. The process is depicted in Figure 4.2.

The second database used was SABINET (South African database) to search for peer reviewed articles in the South African manufacturing landscape – see Figure 4.3.

The third database used was Google scholar. Figure 4.4 shows this process.

The publications were searched on Scopus, SABINET and Google Scholar databases. The Scopus database was the first search engine used due to the availability of only peer reviewed articles in the database. It was decided to initially not allocate a time period to the search as it would be decided after the search whether there would a limit based on the relevance to a specific time period from examining the articles.

The basic keywords used for the search were “energy efficiency” and “manufacturing” and the first search performed on the Scopus database using the word AND. The search was limited to English only resulting in 723 titles. The search was also filtered for the highest cited. Then the search was constrained to article titles which yielded 203 results. It was then necessary to identify the relevant articles by doing the following:

- Reading the titles and abstracts of the articles;
- Excluding the articles referring to information technology used in energy efficiency;
- Excluding the articles referring to specific sectors such as tractors, metals, transportation, electricity generation, etc.
- Excluding articles referring to bio energy, bio fuels and solar power.

This exercise resulted in 59 results.

Next, the article with the highest number of citations was identified with 171 references. The duplications from the first search were then excluded by reviewing the titles resulting in 41 results. Then the following exclusions were done by reviewing the abstracts of the articles:

- excluding the articles referring to information technology used in energy efficiency;
- excluding the articles referring to specific sectors such as metals;
- articles which could not be accessed.

This exercise yielded 9 results.

From the previous 2 searches it was identified that there was only one result relating to South Africa. Therefore the Sabinet database was then searched for peer reviewed articles in the South African manufacturing landscape. This search yielded only 2 results.

Next Google Scholar was used to search for additional articles using the keywords “energy efficiency” AND “manufacturing” resulting in 561 results. The following process was then applied by reviewing the titles and abstracts:

- Removed duplicates from previous searches;
- Excluded the articles referring to information technology used in energy efficiency;
- Excluded specific industry such as metals, transportation;
- Included open access articles.

This resulted in 10 additional results.

The literature review was concluded when saturation was reached as all the references began leading back to the articles already identified.

In total 80 results were yielded from the searches.

In addition to the abovementioned search in terms of peer reviewed articles, the author also accessed two programmes, The National Business Initiative (NBI) Private Sector Energy Efficiency programme (PSEE) and the National Cleaner Production Centre (NCPC-SA) resource efficiency programme.

The NBI PSEE programme was reviewed reflecting trends showing the various types of energy efficiency projects plotted against the payback period in years.

In addition the case studies from the National Cleaner Production Centre's website were evaluated in terms of the extent to which energy efficiency was applied in the manufacturing sector. Companies' energy efficiency interventions were reviewed in terms of the types of projects implemented, as well as which of the companies implemented energy management systems at their companies to be able to provide an indication of the extent of implementation of energy efficiency in the South African manufacturing sector.

Table 4.1 is a summary of the case studies, energy efficiency projects, capital investment and payback.

Table 4.1: Summary of the National Cleaner Production Industrial Energy Efficiency Programme case studies

Project	**Energy Efficiency Intervention**	**Capital invest ment**	**Payback**
Umbilo Ethekwini Water & Sanitation	Aerator-use pattern optimisation. Reduce use of four 75kW aerators from 59h per day to 46h per day. (The aeration tank at Umbilo WWTW consumes about 83% of the total energy of the West Plant)	Not provide d	0.08 years
Altech	Lighting: Replaced with new energy efficient light sources; compressed air: detected and repaired leaks	R 34 500	0.14 years

Project	Energy Efficiency Intervention	Capital investment	Payback
Consol Glass	Fan system optimisation project	R1,948 018	1.2 years
Gastro Foods	Optimizing steam system, compressed air pressure reduction, lighting, install efficient smoker door seals	R237, 500	1.8 years
Rhodes Food Groot Drakenstein	Electricity tariff, lighting, condensate return, improve boiler efficiency, conversion of steam injection system to heat exchanger,, training and awareness, design and procurement process changes	R844, 800	0.24 years
Sundays River Citrus Company	Checking and tracking energy performance	R0	N/A
ArcelorMittal Saldanha Works	Compressed air system, power optimisation, switch off awareness, utilising chemical energy during winter peak, reduce foamy slag, optimise transformer operation, switch off systems during standby	R500, 000	0.01 years
Johnson Matthey South Africa	Optimise compressors and chillers, optimise production mixing vessel operating times, oven optimisation, behavioural changes, improve production efficiencies	R620, 000	0.08 years
SAPPI Cape Kraft	Switch off Frotapulper when making certain grades of paper, Switch off Top Line Refiner when making certain grades of paper, Switch off Rewinder in the Paper Machine when not required, Switch off Cameron Winder in the Coater Plant when not required, Implement a steam trap maintenance programme	R70, 000	0.2 years
Zimalco	Furnace retrofit and expansion, utilisation of waste heat, behavioural changes and operational control improvement	R335, 000	Less than 1 year
Durbanville Hills Winery	Demand management, chilled water plant optimisation, lighting, compressed air system optimisation	Not availabl e	Not available
Distell Adam Tas	Switch off compressors over weekends, plant optimisation, lighting, install timers on cooling compressors	R956, 960	1.4 years
Klein Karoo International	Control of boiler feed air, repair condensate leaks, repair steam leaks	R66 500	0.4 years
Gledhow Sugar Company	Staff energy awareness and training programme, detailed survey of the steam distribution network and improvements to thermal insulation, improvements to boiler controls, implementation of a steam trap and steam leak maintenance programme to reduce leaks	R210 000	0.5 years
Precision Press	Switching off electrical equipment, repairing compressed air leaks	R66 265	0.14 years

Project	Energy Efficiency Intervention	Capital investment	Payback
Techniplate Electroplaters	Installation of temperature controller and energy meters for 42 tanks	R46 200	0.33 years
Toyota SA	Occupancy sensors were placed in large offices, inefficient overhead ventilation systems were replaced with smaller localised systems, solar water heating was installed in two ablution systems, lighting	R3,350 000	1.09 years
Feltex Automotive	Installation of small air compressor to supply weekend load, replace resistive heater coils with infrared lamps, installation of buffer plates, use of natural light	R197 600	1.98 years
SOCKIT Manufacturing	Fuel switch, steam system optimisation, compressed air leaks	R550 000	4 years
Toyota Boshoku SA	Replacement of existing lighting technologies with new, energy efficient technologies	R451 840	1.85 years
Tenneco Automotive	Compressed air optimisation, lighting initiatives, paint shop burner submersion tube, automatic metering, new chrome planting oven, power factor correction, Training.	R3,100 000	1.55 years
King Shaka International Airport	Internal and external lighting initiatives, optimisation of air conditioning systems.	R400 641	1.8 years
Polyoak Packaging	Cooling tower fan and pump optimisation, cooling recirculation system optimisation, insulation jacket for barrel extruder, training and basic energy awareness	R262 133	0.1 years

Research objective 3: evaluation of the effectiveness of energy efficiency in AECI's Green Gauge Resource Efficiency Programme

Analysis of quantitative data:

As discussed in the case study section, energy assessments were conducted by external consultants and opportunities databases were developed for each of the manufacturing sites including detailed information for each of the energy efficiency opportunities that was identified.

The first step in the assessment involved transferring all the relevant data into one consolidated spreadsheet. As the opportunities databases included information for energy, water and waste it was firstly important to only copy across the energy efficiency information to the consolidated spreadsheet. Data relating to 292 opportunities that were identified across the 16 manufacturing sites was copied into the consolidated spreadsheet and categorised according to the following headings:

Operation (facility), Industry sector, Type of measure, Opportunity title, Opportunity description, Basis of calculation, Capital cost, Primary savings, Primary savings per type (e.g. coal, gas, electricity), Energy savings (kWh), Financial savings, Payback.

Two further columns were introduced: Project category and Implementation flag.

The project category was introduced to categorise the type of measures into broader categories. The following categories of energy efficiency measures were created:

- Control – measures to reduce the temperature or pressure and other operational parameters to optimise efficiency.
- Energy management – metering and targeting, optimise electricity use etc.
- Energy recovery – optimise condensate recovery.
- Equipment replacement - replacing motors and other equipment with more efficient equipment.
- Housekeeping – general management improvements such as cleaning filters, keeping the cold storage door closed, improving maintenance.
- HVAC – Improving heating, ventilation, air conditioning systems to be more efficient.
- Leak detection and repair/insulation repair – detecting and reducing leaks; insulating valves, flanges, pipes, hot baths, storage vessels; repairing leaks on steam and compressed air systems.
- Lighting – lighting sensors, replace with more efficient lights, improved lighting management, use of natural lighting, control of lights, warehouse lighting optimisation, day/night switches etc.

- New equipment – installation of new, more efficient equipment such as gas boiler, inverters, heat pump, chiller, dessicant, etc.
- Redesign – update or redesign process to be more energy efficient, especially where processes were fairly dated.
- Renewable energy – included opportunities such as solar water geysers.
- Removal of redundant equipment – this included removal of equipment that was impacting on energy efficiency such as original air flow dampers to reduce system losses.
- Steam traps – projects relating to steam trap maintenance, repair and optimisation.
- Switching off/reduction in hours – typically included switching off equipment or operations when not in use such as boilers, centrifuge pumps, chillers.
- VSDs – installation of variable speed drives on equipment to allow for additional energy saving and better control.

The implementation flag column was introduced to be able to filter between the implemented and not implemented projects, using TRUE or FALSE keywords to distinguish between implementation and non-implementation.

The data were then analysed by filtering the various categories in the columns to generate trends to be able to deduce findings, relationships, anomalies and to further link the results with the data from the qualitative aspect (questionnaire results). Key trends developed from the data were % implemented per facility, projects implemented by capital investment, projects implemented by energy savings, % implemented by project type, projects implemented by payback, projects implemented vs not implemented per various category (low capital, low payback; no capital, no payback; low capital, high payback).

Data and key findings from the qualitative assessment (explained below) were then used to elaborate and corroborate the quantitative findings. This method of mixed method design is referred to as the Explanatory Sequential Design (Bryman & Bell, 2015:646).

Assessment of qualitative data:

Questionnaires were completed by site personnel, typically programme managers that were involved and had oversight over the Green Gauge programme at the manufacturing sites that participated in the programme. The programme managers represented disciplines across engineering, operations and safety, health and environment. The manufacturing sites represented the following sectors in the chemical sector:

- Food
- Property services
- Mining chemicals and solutions
- Agriculture
- Industrial and consumer specialty chemicals
- Water treatment

As the participants selected to answer the questionnaire were identified through their direct involvement in the Green Gauge programme the sampling method was purposive or judgemental.

The questionnaire distributed to the programme managers included the following questions (see Appendix A):

Do you think the Green Gauge programme was beneficial in achieving energy savings for your facility? Please expand.

What were the factors driving implementation of energy efficiency opportunities identified at your facility?

Were you able to easily motivate for capital for energy saving projects? Explain.

What were some of the challenges faced with AECI's Green Gauge programme?

Would you support a programme similar to Green Gauge for your facility in the future? Explain.

Please provide a few improvement opportunities related to the Green Gauge programme.

The questionnaire (see Appendix A) was distributed to candidates who had been identified as directly involved in the Green Gauge programme in the period 2011 to 2015. Where key individuals had left the company, a colleague who worked with the individual and had sufficient involvement in the programme, was approached to respond to the questionnaire. The participants ranged from engineers to safety, health and environmental (SHE) managers or SHE officers.

The questionnaire was designed to extract information relevant to the following research objectives:

- To evaluate the effectiveness of energy efficiency in AECI's Green Gauge Resource Efficiency Programme.

Table 4.2 indicates the number of invitees and their participation and response rates:

Table 4.2: Questionnaire participation and response rates

Invitees	16
Number contacted to answer questionnaire	16
Did not respond	2
Invitees responded	14
Total responses	14
Participation rate	87.5%
Invalid responses	0
Valid response rate	87.5%

Analysis of qualitative information or data involves ‘cutting data up to put it together in a manner that seems relevant and meaningful’ (Harding, 2013:4).

A coding methodology was used to identify categories and sub-categories of drivers and barriers to implementing energy efficiency from the questionnaire responses. The following method was used (using Excel) based on methodology according to Aurini et al. (2016:186).

Using the copy and paste function, responses were included in an Excel spreadsheet per site and per questionnaire. Then using a colour coding system common themes relating to drivers and barriers to energy efficiency were highlighted from the responses to the following questions:

- Do you think the Green Gauge programme was beneficial in achieving energy saving for your facility? Please expand.
- What were the factors driving implementation of energy efficiency opportunities identified at your facility?
- Were you able to easily motivate for capital for energy saving projects? Explain.
- What were some of the challenges faced with AECI’s Green Gauge programme?
- Would you support a programme similar to Green Gauge for your facility in the future? Explain.

In a new Excel worksheet, the themes that were colour coded were copied and pasted into cells and then mapped to a category of a key driver or barrier. Trends were then developed from the data and analysis was performed and used to corroborate and elaborate on the quantitative data. The trends and key themes were then used to discuss key findings, relationships and common and emerging themes in the Results section.

The next chapter provides an account of the results.

Chapter 5: Results

In this chapter the quantitative and qualitative data will be presented and discussed. The results of the main research objective, Objective 3, to evaluate the effectiveness of energy efficiency in AECI's Green Gauge Resource Efficiency Programme, used a mixed method to assess the effectiveness of the programme at each AECI manufacturing site that participated in the Green Gauge energy efficiency programme.

The results are presented with the aim of addressing the research objective on whether the energy efficiency component of the Green Gauge programme was effective, as well as provide key insights and recommendations to companies in the manufacturing sector wishing to embark on an energy efficiency programme.

The results are analysed in two parts: Drivers and barriers towards implementing energy efficiency measures and the extent of energy efficiency realised through AECI's Green Gauge Programme. Thereafter a model incorporating insights and findings from the results is proposed.

5.1. Drivers and barriers towards implementing opportunities

By performing coding on the responses to the questionnaire, key themes were identified. These themes were categorised into either drivers for, or barriers to, implementing energy efficiency measures. Table 5.1 provides a summary of the key drivers identified and the keywords or phrases in the responses.

Table 5.1: Key drivers identified from the responses to the questionnaire

Driver categories	**Technical expertise**	**Efficiency/ cost savings**	**Reduce waste**	**Compliance/ EMS**	**Environmental**	**Low cost opportunities**
Keywords/phrases identified in responses	*Expert consulting team*	*Improvements*	*Wastage*	*Compliance*	*Global warming*	*Did not require major capital*
	Energy survey by expert consulting team	*Efficiency*	*Waste reduction*	*ISO 14001*	*Sustainable future*	*Most of the projects did not require capital expenditure*
	Fresh pair of eyes	*Energy savings*	*Waste*	*Compliance*	*Environmental*	*Immediate payback with less capital expenditure.*
	Energy assessment	*Accelerate energy saving initiatives*	*Save resources*	*International standards*	*Reducing greenhouse gases*	*Opportunities did not require any capital costs upfront*
	Internally identified opportunities	*Cost saving initiatives*	*Ideas*		*Environmental sustainability*	*Minor operational changes*
		Improvements in energy consumption	*Reduction of resources*		*Environment*	
		Save resources	*Wasting resources*			
		Operating costs				
		Monetary savings				
		Cost saving				
		Cost				
		Cost reduction				
		Cost reductions				

Table 5.2 provides a summary of the key barriers identified from the responses to the questionnaire.

Table 5.2: Key barriers identified from responses to the questionnaires

Barrier categories	**Organisational (lack of resources)**	**Organisational (buy-in)**	**Infrastructure**	**Capital and Access to capital**	**Training/ awareness**
Key words/phrases identified in responses	*Resources*	*Managers did not have much belief in programme*	*Some recommendations could not be implemented*	*No budget*	*On boarding of management and staff*
	Needed individual dedicated to project	*Buy-in from staff*	*Age of facility and equipment*	*High maintenance costs*	
	Resources	*Buy-in*	*Layout of facility*	*Cost estimates were lower than actual cost*	
	Not overseen by process engineer or engineering manager	*Not driven from top*		*Costing*	
		Mind-set		*Justifying projects for long term savings*	
		Getting operational staff to work with consultants			

The drivers and barriers identified in the responses to the questionnaire are discussed in light of information obtained from the facilities in terms of the projects identified, implemented and not implemented. This includes information on technology type, responsible person, capital cost, energy savings, financial savings and payback.

The drivers for energy efficiency identified by the sites and the percentage of projects implemented are depicted in Figure 5.1:

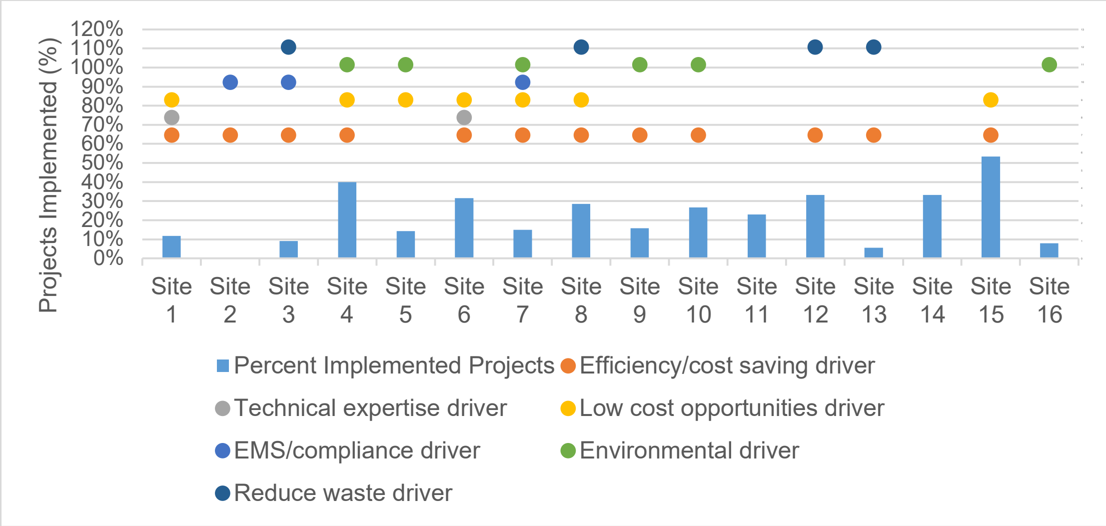


Figure 5.1: Percent of projects implemented by sites and the drivers identified

The site which had the highest percentage of projects implemented identified both efficiency/cost saving and low-cost opportunities as a driver. The driver identified by the majority of the sites was low cost opportunities. Sites 11 and 14 did not participate in the survey, as indicated in Table 4.2, therefore no drivers were cited.

The barriers for energy efficiency identified by the sites and the percentage of projects implemented are depicted in Figure 5.2:

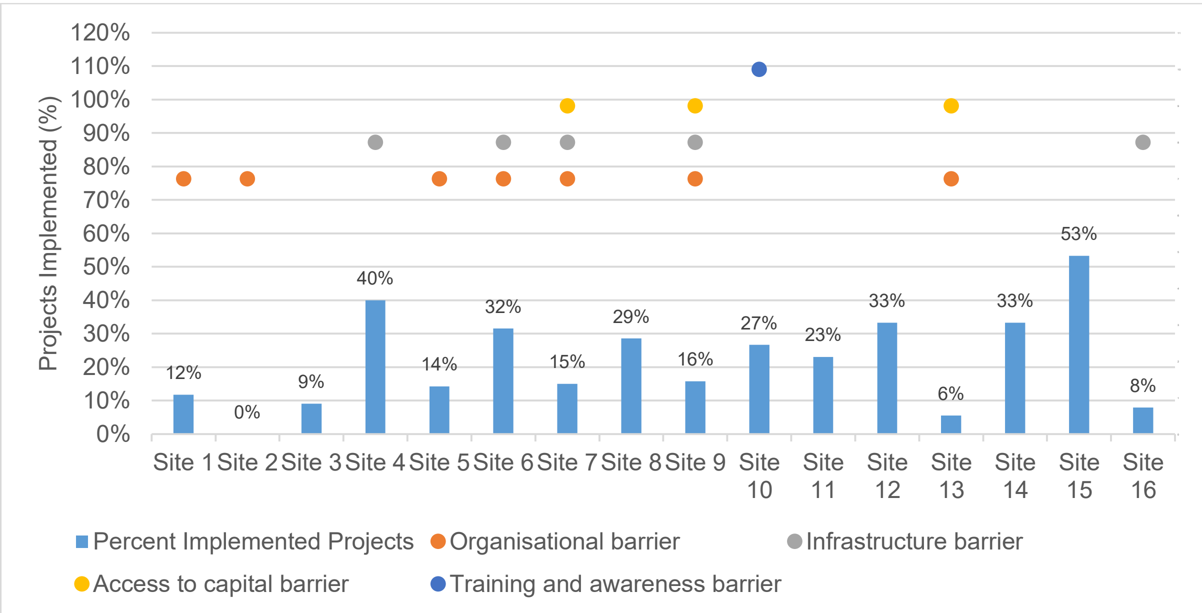


Figure 5.2: Percent of projects implemented by sites and the barriers identified

The site which had the highest percentage of projects implemented did not identify any barriers to energy efficiency. This is the case for most of the sites where percentage of projects implemented is 33% or above. However, Site 4, with 40% of its identified projects having been implemented, reports a barrier relating to infrastructure. The most common barrier appears to be organisational in nature (i.e. buy-in and resources). Sites 11 and 14 did not participate in the survey, as indicated in Table 4.2, therefore no drivers were cited.

Each of the drivers and barriers is discussed in more detail below:

5.1.1. Drivers for energy efficiency

5.1.1.1. Efficiency/cost saving

Cost saving was the most identified driver by more sites than the other drivers – 69% (11 out of 16 sites) stated that the opportunity for cost saving was a driver for energy efficiency. One site, for example, stated that the main driving factor was 'the cost reductions in resources and increased efficiencies on the plant.' The sites that identified cost saving as a driver typically also reported a higher percentage of implemented projects:

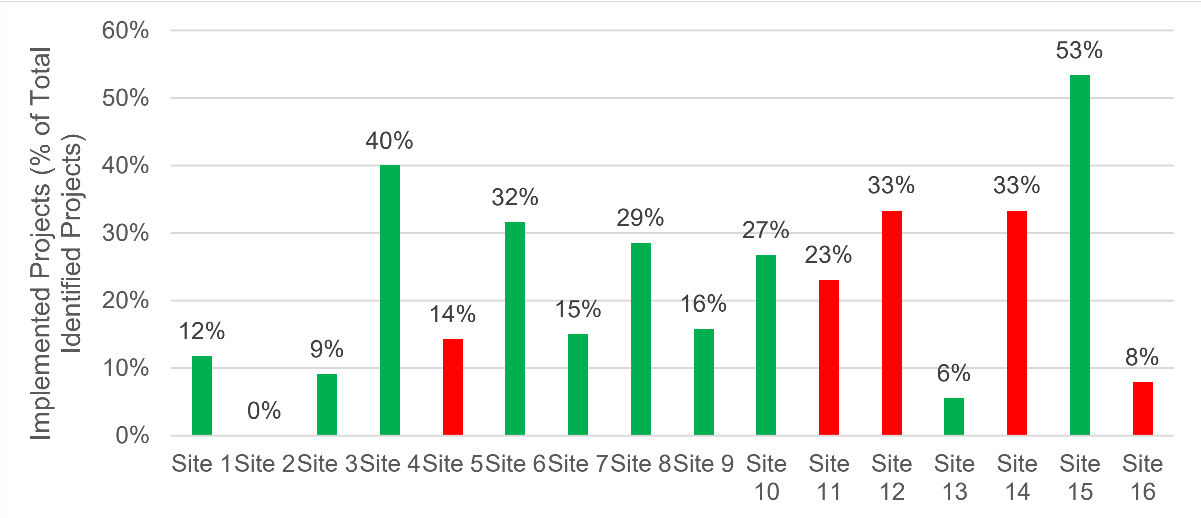


Figure 5.3: Percent of projects implemented by sites claiming that cost saving was a driver

In Figure 5.3 above, the green bars are where the sites identified cost saving as a driver whereas the red bars are for the sites that did not identify cost saving as a driver. Note that the site with the highest number of implemented projects identified cost saving as a driver. However, there are also some sites that identified cost saving as a driver but didn’t implement any projects or implemented only a low percentage of identified projects. This suggests that there were possibly barriers to the implementation of energy efficiency measures experienced by these sites.

The identification of cost saving as a key driver for energy efficiency aligns with what has been found in the literature review. The fact that the responses to the questionnaire highlight cost saving seems to suggest that any programme implemented should focus on how it will realise cost saving for the company.

5.1.1.2. Technical expertise driver

The use of specialists or technical experts was identified as a benefit of the Green Gauge Programme in the responses to the questionnaire. One respondent highlights that ‘At programme inception, a consulting team, whose specific area of expertise was energy conservation, was used to assist our operations staff to generate ideas where improvements could be made.’ Another respondent states that ‘This programme afforded us an opportunity to have someone with a fresh pair of eyes to assist in identifying inefficiencies and wastage.’

In order to understand whether this was a driver for implementing energy efficiency measures, the percentage of projects implemented by sites claiming that the use of specialists was of benefit, is compared to the percentage of projects implemented by sites that do not make this claim (See Figure 5.4).

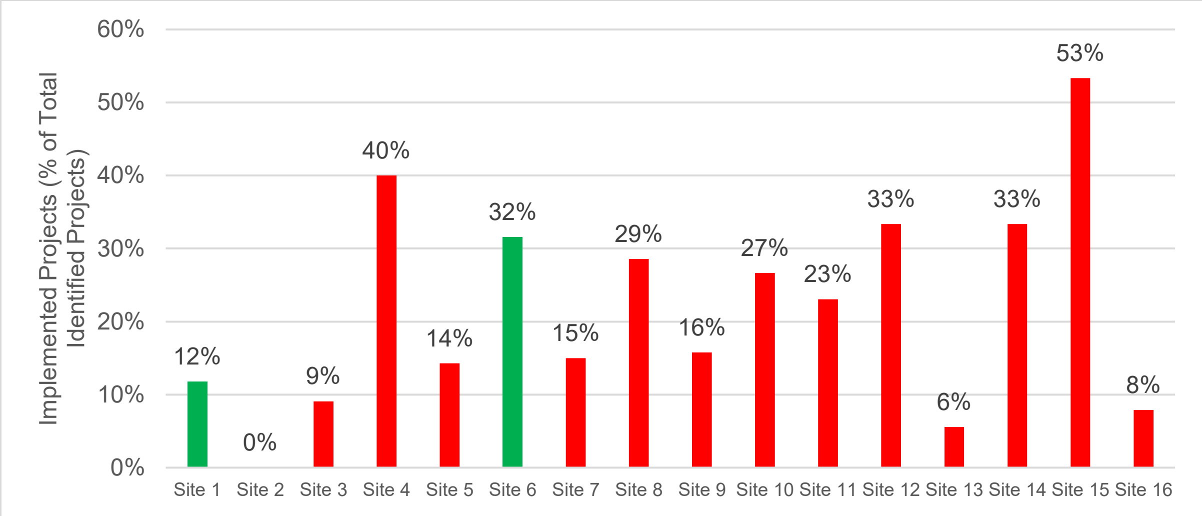


Figure 5.4: Percent of projects implemented by sites claiming that technical expertise was a benefit

In Figure 5.4 above, the green bars are where the sites identified technical expertise as a driver whereas the red bars are for the sites that did not identify technical expertise as a driver. Sites 1 and 6 identified the use of specialists as being of benefit. However, these sites do not have the highest percentage of projects implemented. This may suggest that – although the specialists were instrumental in identifying projects – it did not necessarily mean that this led to project implementation.

One of the sites notes that using the correct technical expertise is critical. The response from this site suggests that the first assessment of energy efficiency measures was not useful, but findings from subsequent assessments by different consultants were useful and formed the basis of the site's energy saving initiatives.

The number of sites that identified technical expertise as a driver is less than the number of sites that identified cost saving as a driver.

5.1.1.3. Reduced waste driver

The Green Gauge Programme was broader than energy. It also focused on water and waste. Some of the sites highlight reduced wastage as a driver under the programme. Elimination of waste and better and more efficient use of resources are included in responses from three of the sites (See Figure 5.5).

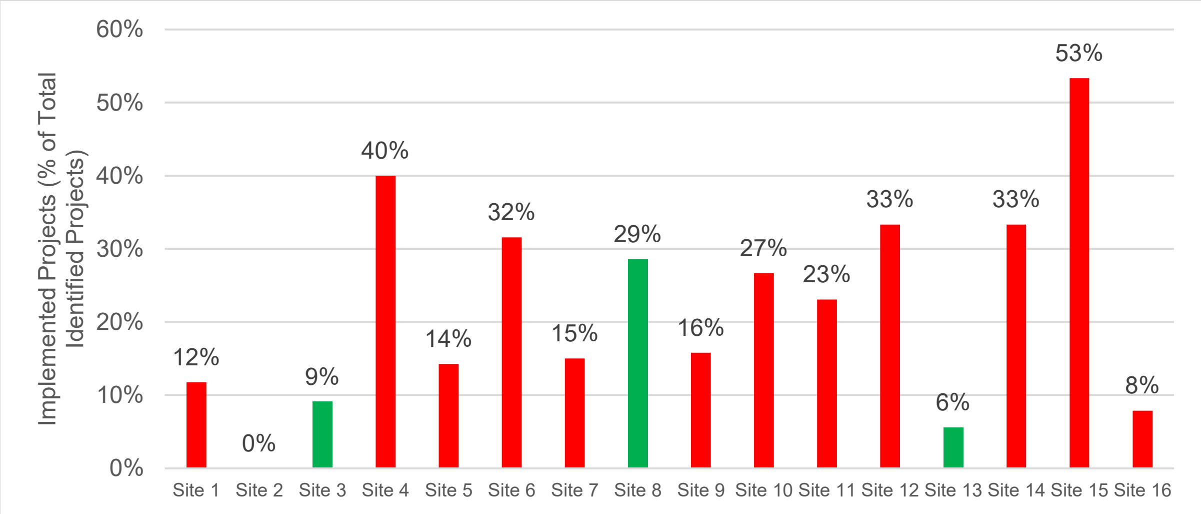


Figure 5.5: Percent of projects implemented by sites claiming that reduced wastage was a driver

In Figure 5.5 above, the green bars are where the sites identified reduced wastage as a driver whereas the red bars are for the sites that did not identify reduced wastage as a driver. Sites 3, 8 and 13 identified reduced wastage as a driver. However, none of these sites reported the highest percentage of implemented projects. In addition, only three sites identified this as a driver whereas 11 sites identified cost saving as a driver. This suggests that cost saving is more of a driver than reduced wastage. Reduced wastage would, however, lead to cost saving.

5.1.1.4. Environmental and compliance drivers

Interestingly, environmental protection came to the fore as a major theme in the responses. Some of the responses highlight this as being a driver. One site, for example, highlights the importance of ‘curbing global warming because the recent changes in the weather patterns, for example floods, have caused damage to some of the facilities and often cause down time’.

Other sites also identified compliance as a driver. However, in this case, compliance refers to compliance to AECI’s internal standards, or to international standards, or ISO 14 001. One site reports that it was a new acquisition to AECI at the time of the implementation of the Green Gauge Programme and that the programme was useful in aligning it to AECI's Safety, Health and Environmental (SHE) Management standards and international standards.

The sites that report either environmental or compliance drivers are depicted in Figure 5.6:

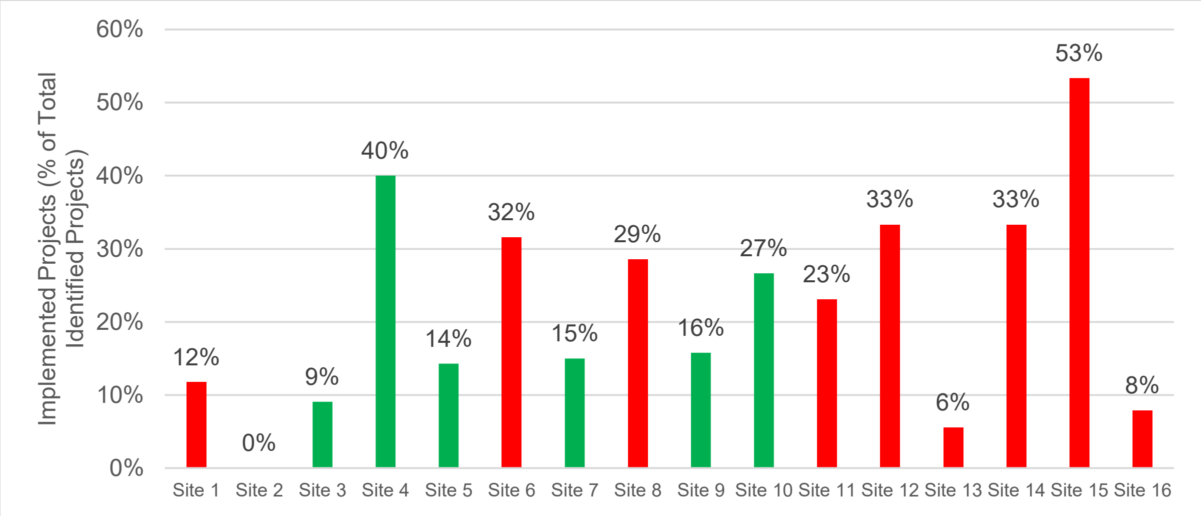


Figure 5.6: Percent of projects implemented by sites claiming that environmental protection or compliance were drivers

In Figure 5.6 above, the green bars are where the sites identified compliance or environmental protection as drivers whereas the red bars are for the sites that did not identify compliance or environmental protection as drivers.

The site with the highest percentage of projects implemented did not identify any environmental or compliance drivers. However, the site which had the second highest percentage of projects implemented, was the site that identified the need to reduce greenhouse gas emissions as a driver. This site also identified both cost saving and low-cost opportunities as drivers so the high percentage of projects implemented may not necessarily have been driven only by environmental concerns.

5.1.1.5. Low cost opportunities driver

One of the drivers for project implementation was identified to be low capital cost. Respondents indicated that one of the benefits of the Green Gauge Programme was that many of the identified projects did not require significant capital investment. Some even required no capital investment. The sites having identified this as a driver are depicted in Figure 5.7.

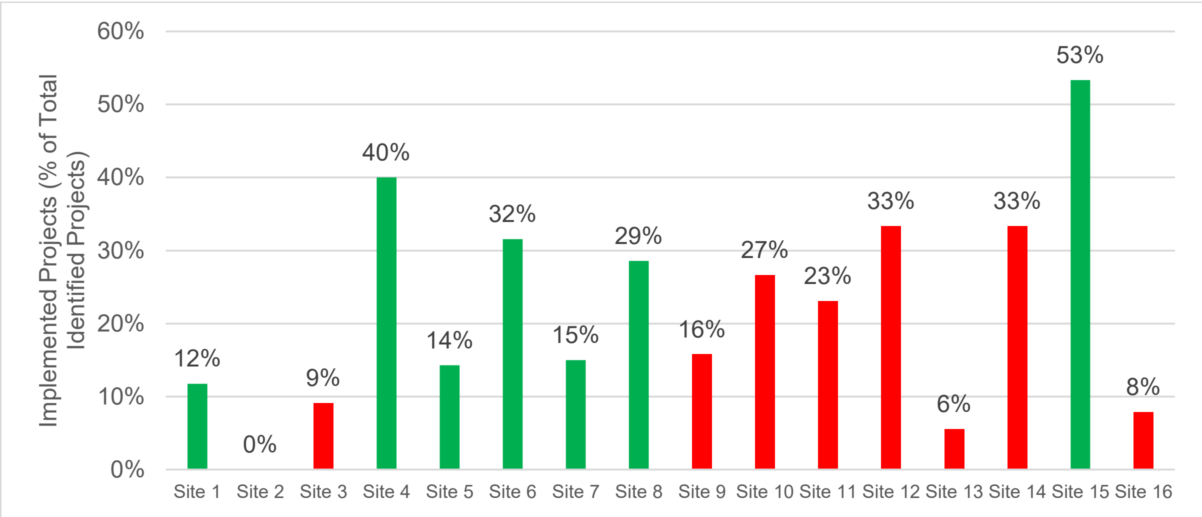


Figure 5.7: Percent of projects implemented by sites claiming that low cost opportunities were a driver

In Figure 5.7 above, the green bars are where the sites identified low cost opportunities as a driver whereas the red bars are for the sites that did not identify low cost opportunities as a driver. The sites with the highest and second highest percentage of projects implemented appear to have identified low cost opportunities as a driver. One of the sites refers to the benefit of having identified opportunities with low payback and low capital.

However, there are also some sites which implemented in excess of 30% of the identified projects but did not mention low cost opportunities to be a driver.

5.1.2. Barriers

5.1.2.1. Capital cost and access to capital barriers

In the responses to the questionnaire, one of the barriers identified is high upfront capital cost. Some of the respondents indicated that it was not easy to motivate for capital for projects where the capital cost was high. According to one respondent, the company started off by implementing projects which required little or no capital investment. Yet another respondent notes that it was easier to motivate for projects that had a lower capital expenditure than those with a higher capital expenditure. High upfront capital cost was also identified as a barrier in literature.

The abovementioned is further supported by the results presented in the graph below (See Figure 5.8).

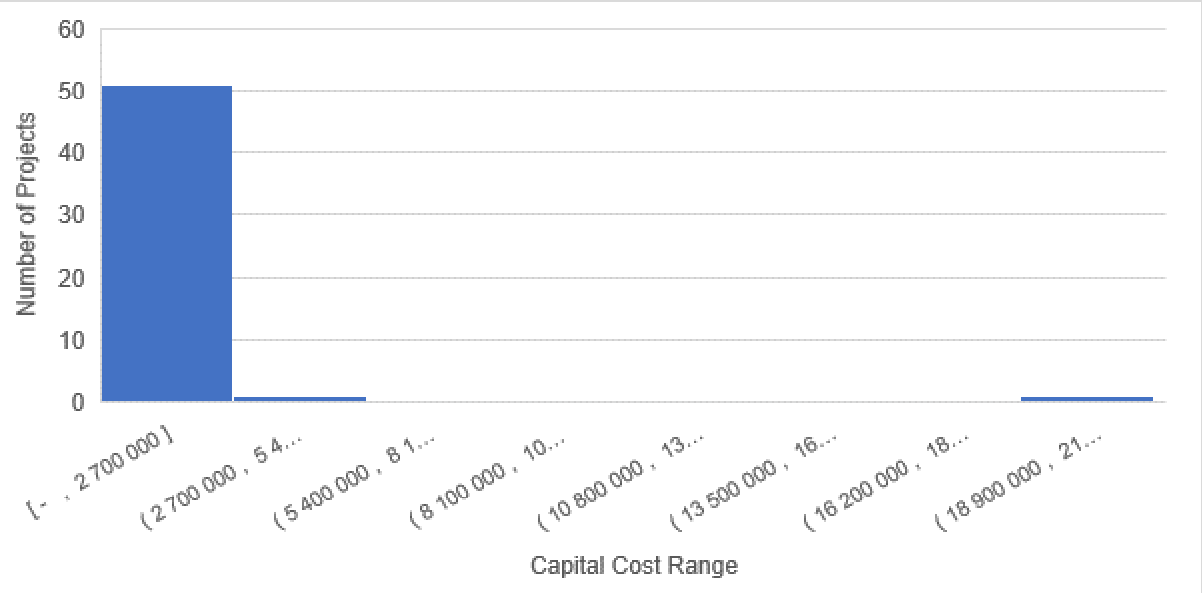


Figure 5.8: Histogram of capital cost of implemented projects

If only the projects with a capital cost below 2.7 million are depicted then the following trend is reflected (See Figure 5.9).

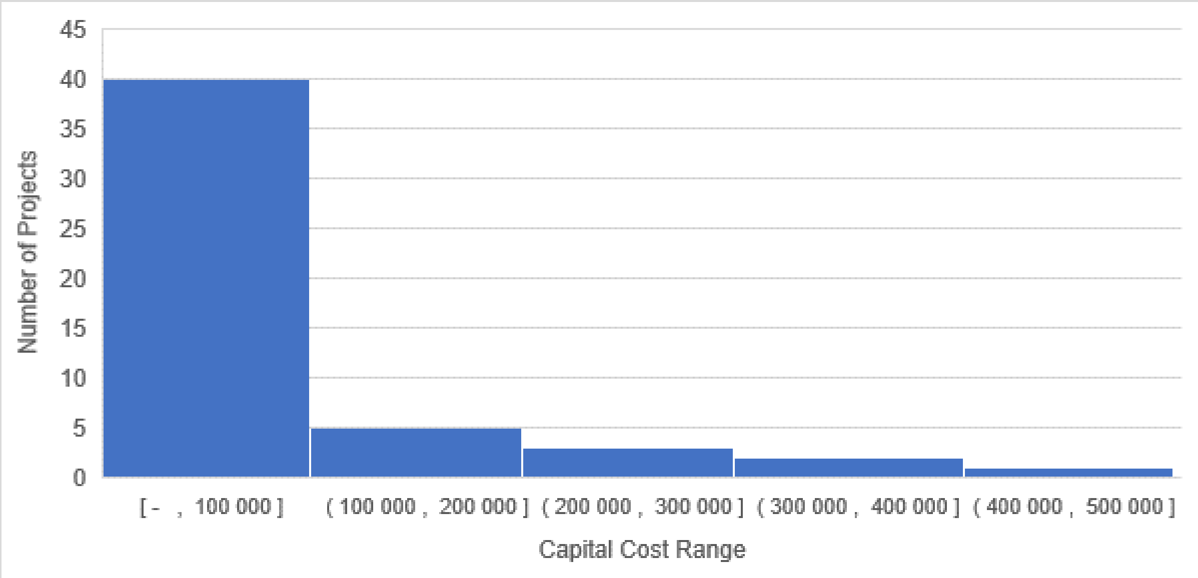


Figure 5.9: Histogram of capital cost of implemented projects where capital cost is below R2.7 million

The histogram in Figure 5.9 shows the capital cost of the implemented projects. Of the abovementioned, most of the implemented projects had a capital cost of less than R100,000. All of the implemented projects, except two, had a capital cost of less than R500,000. Note that the capital cost of the identified projects ranged from R0 to in excess of R20 million. This seems to suggest that focus was placed on implementing low capital cost projects.

The two projects which had capital costs in excess of R500,000 were implemented for other reasons. For example, there is one project in Figure 5.9 which has a capital cost far in excess of the other projects. The capital cost for this project is higher than R20 million. This was a fuel switching project. It was implemented as it demonstrated other social and environmental benefits which are described in the Case Study chapter. The project was driven by environmental considerations which also emerged from the responses to the questionnaire to be a driver for energy efficiency.

In some cases, capital cost was seen as more of a driver than payback period. The relationship between capital cost and payback period for all identified projects is depicted in Figure 5.10:

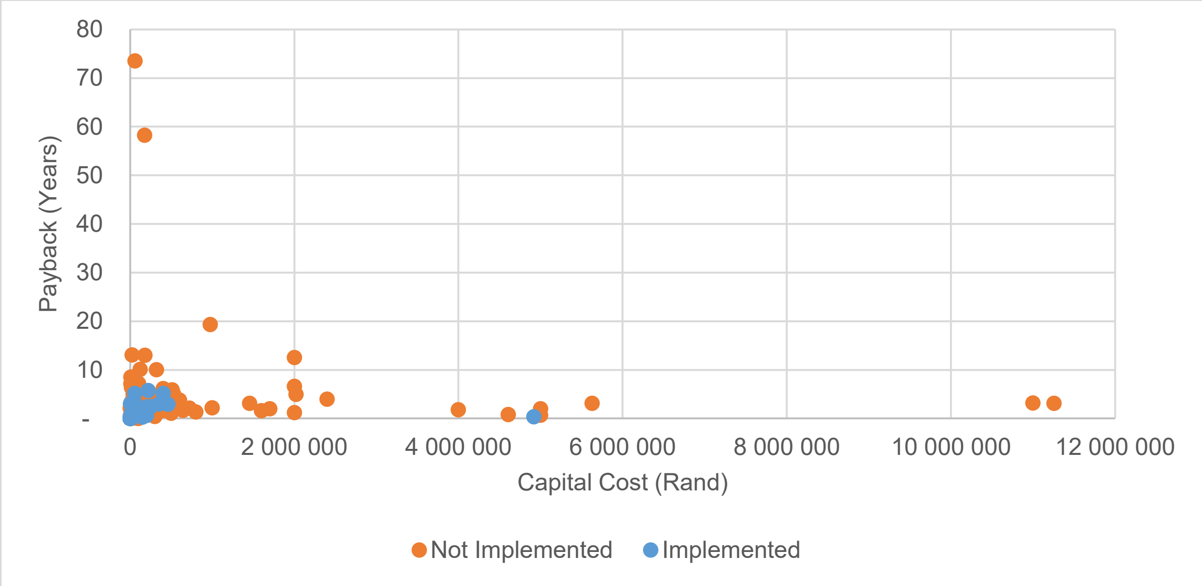


Figure 5.10: The relationship between capital cost and payback period for implemented and not implemented projects

Similar to Figure 5.9, the graph in Figure 5.10 illustrates that the majority of the implemented projects had a capital cost of less than R500,000. This is a clear indication that projects with a low upfront cost were favoured over those with a high upfront cost. Note that the fuel switching project referred to above has not been included in Figure 5.10.

If the not implemented projects are removed from Figure C, the following results are shown in Figure 5.11 below:

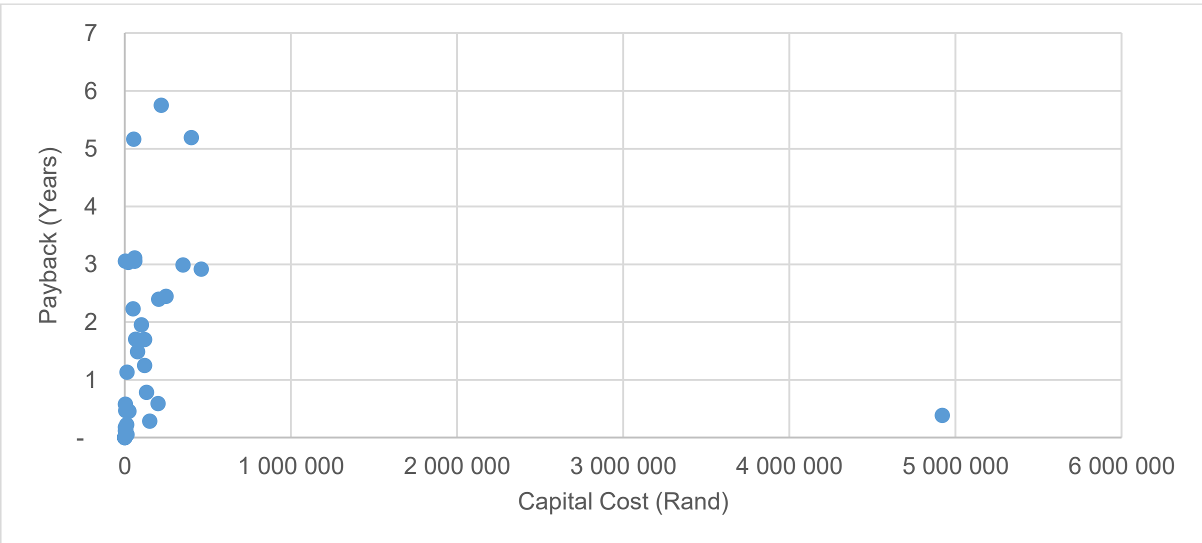


Figure 5.11: The relationship between capital cost and payback period for implemented projects

From Figure 5.11, it is evident that there were several energy efficiency measures which had a low capital cost, but a payback period in excess of three years. Three years is highlighted as a typically acceptable payback period in literature. These projects related to energy efficient lighting and control, switching off equipment when not in use and the implementation of Variable Speed Drives (VSDs). Despite the longer payback periods, there projects were still implemented due to the low capital cost. This could illustrate that a low capital cost plays a far greater role in the decision-making than a low payback period.

There is one project with a capital cost close to R5 million in Figure 5.11. This project also relates to a fuel switching project. It was implemented to allow the site to sell the fuel it was previously using in the burner to realise another revenue stream for the site.

Access to capital was also identified as a barrier in the responses to the questionnaire. The lack of a dedicated budget for the Green Gauge Programme resulted in it taking a long time to implement certain of the recommendations, with some not being implemented at all due to capital cost requirements. According to one respondent, often energy efficiency measures are competing for capital against other important projects. Another respondent highlights the slow nature of the capital approval process and the focus on implementing no or low capital cost projects so as to avoid this lengthy process. This aligns with the suggestion by one of the respondents to have a dedicated budget in place to improve the Green Gauge Programme.

With regards to access to capital, it is interesting to note that only 23% of the respondents noted that it was difficult to motivate for capital whereas 54% of the respondents noted exactly the opposite, namely that it was not difficult to motivate for capital (See Figure 5.12). However, some of these respondents cite low capital cost projects in their justification. Another respondent states that the site had recently relocated and this affected the motivation for capital. Still, other sites state that it was easy to motivate for capital, but then identify the lack of a dedicated budget as one of the challenges associated with the Green Gauge Programme.

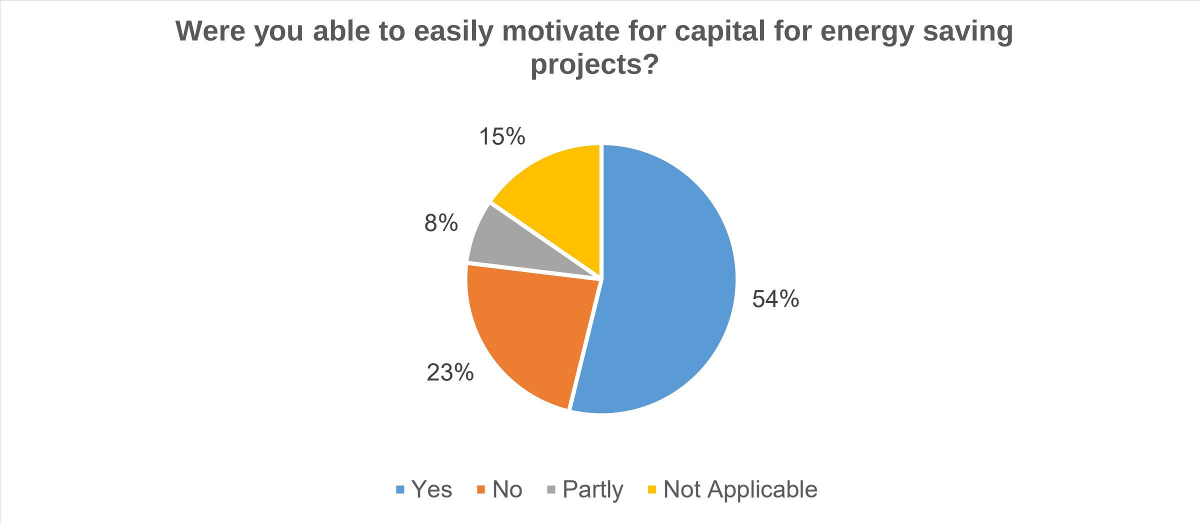


Figure 5.12: Responses to the question: Were you able to easily motivate for capital for energy saving projects?

Interestingly, it was found that a large number of projects not implemented had low capital costs as indicated in Figure 5.13:

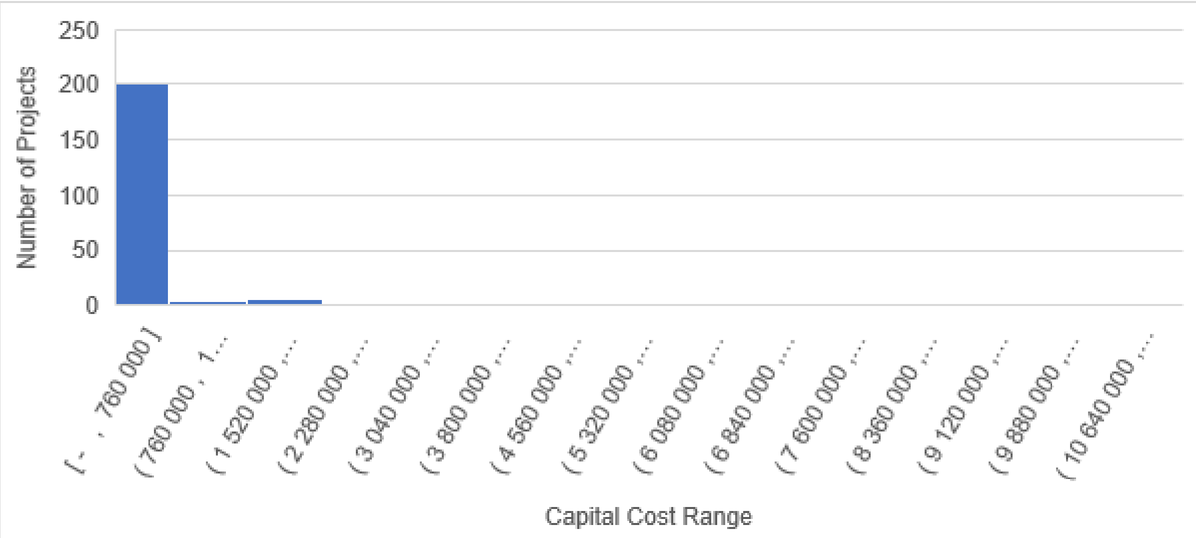


Figure 5.13: Histogram of capital cost of projects not implemented

This seems to indicate that there are other barriers to implementing energy efficiency measures and not only capital cost. Upon further scrutiny, it was identified that 52% of these low capital cost projects were not implemented by sites that did not implement any projects or a very low number of projects. At these sites, other challenges (i.e. compliance, restructuring or reduced production demands) may have resulted in these low capital cost projects not being implemented. For example, one of the sites was impacted by changes to regulations which required it to invest significant capital in order to ensure compliance. For sites with other challenges, the Green Gauge Programme was low on the list of priorities and the sites did not implement any energy efficiency projects.

Some reasons for the remaining 48% of the low capital cost projects not being implemented were cited in the responses to the questionnaire. These included:

- Access to capital: One of the challenges faced at a facility was that at the time of the assessments there was no budget allocated for the Green Gauge programme and it therefore took a long period of time to implement recommendations resulting in some opportunities not being implemented.

- Implement-ability: Several projects could not be implemented as the existing equipment did not accommodate them. For example, at one of the sites, the pumps utilised could not accommodate the installation of VSDs.

- Organisational barriers: Many facilities cite organisational barriers such as lack of buy-in and resources.

One of the other challenges identified that related to capital cost and access to capital, was the incorrect estimate of capital cost when identifying the opportunity and developing the business case. One of the respondents notes that 'The critical challenge was certainly the costing, for most projects the upfront or estimated cost was by degrees of magnitude less than the actual cost. There was also some challenge with the practicality of the costs.' One of the other respondent's notes that the costs were estimated upfront, but that on-going maintenance costs were not considered, leading to high maintenance costs eliminating the other cost saving benefits of the projects.

5.1.2.2. Organisational barriers

Organisation challenges such as resource constraints emerged as a key barrier when assessing the responses to the question *'What were some of the challenges faced with AECI's Green Gauge Programme?'*

Several respondents cited:

- Lack of resources or a dedicated resource to drive the programme;
- Lack of buy-in from the operational staff and/or management;
- Continuity of leadership of the programme;
- Challenges associated with obtaining operational staff's cooperation to work with consultants; and
- The nature of the resources selected to coordinate and drive the Programme at site-level (i.e. Safety, Health and Environmental (SHE) personnel as opposed to technical personnel).

From the literature review, organisational barriers, particularly lack of resources, was identified as a key barrier to implementing energy efficiency measures in developing countries. The responses to the questionnaire seem to support this finding.

Figure 5.14 shows the projects implemented as a percentage of projects identified per site:

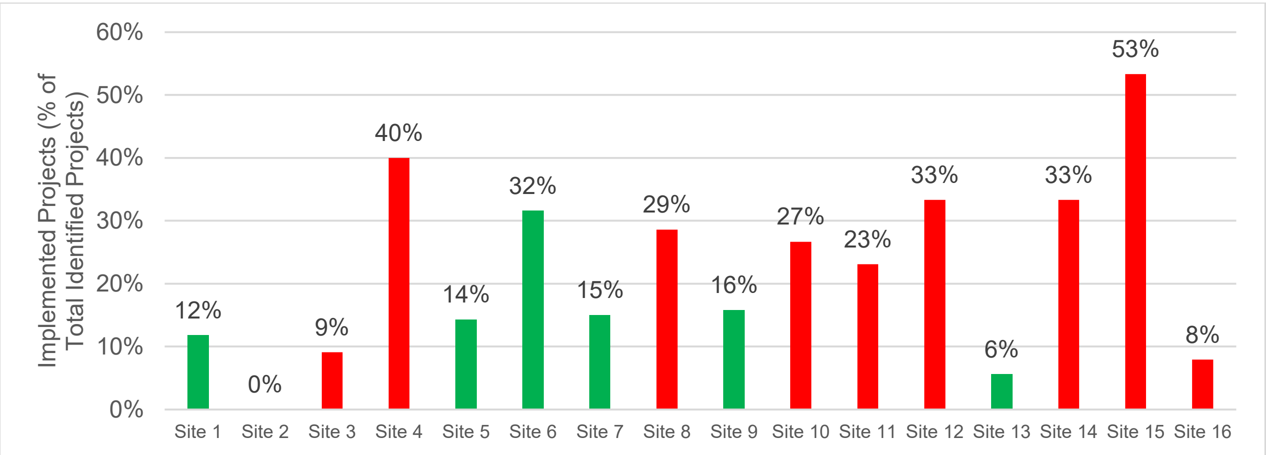


Figure 5.14: Percentage of projects implemented by site that Identified organisational barriers

In Figure 5.14 above, the green bars are where the sites identified organisational barriers whereas the red bars are for the sites that did not identify organisational barriers.

Sites 1, 5, 6, 7, 9 and 13 identified challenges associated with lack of resources and/or lack of buy-in from staff in the responses to the questionnaire. With the exception of Site 6, these sites implemented less than 15% of the identified projects. This seems to indicate that lack of resources and buy-in are barriers to the implementation of energy efficiency measures.

The sites that identified buy-in as a challenge implemented less than 15% of the identified projects. The two sites that identified resourcing as a challenge implemented 14% and 32% of the identified projects respectively. Lack of buy-in appears to be more of a barrier to implementation of energy efficiency measures than lack of resources.

However, it is clear that these are not the only barriers as there were sites that did not identify lack of resources and/or lack of buy-in from staff as challenges and still did not implement any or many projects.

5.1.2.3. Infrastructure barriers

Some of the manufacturing facilities are relatively old, thus it was not surprising that challenges to implementing energy efficiency measures related to aging infrastructure and equipment, where it was not possible to retrofit new technology with old equipment. One site, for example, reports that 'the reason that some suggestions could not be implemented (i.e. in the case of the VSDs) was that the pumps utilised on the site could not accommodate the installation of the VSDs. It would be a costly exercise to replace the pumps to be able to accommodate the VSDs.'

The sites that identified infrastructure-related barriers are indicated in Figure 5.15.

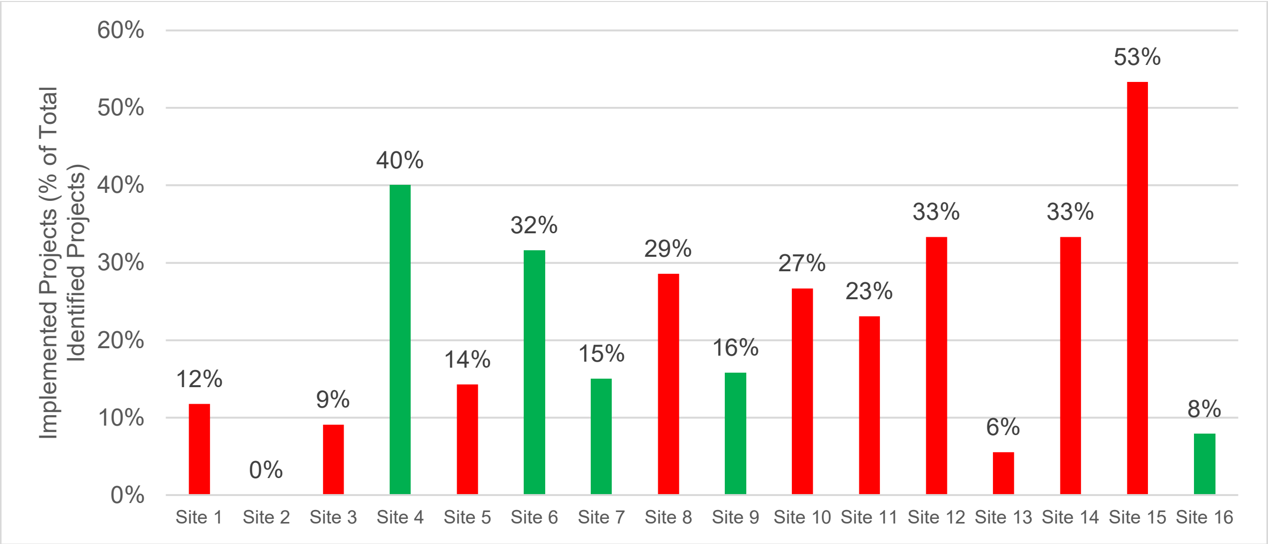


Figure 5.15: Percentage of projects implemented by site that identified infrastructure barriers

In Figure 5.15 above, the green bars are where the sites identified infrastructural-related barriers whereas the red bars are for the sites that did not identify infrastructural-related barriers. Some of the sites that identified infrastructural-related barriers still implemented a significant percentage of identified projects. As such, although it may have resulted in not all projects being implemented, it is clear that infrastructural barriers were not necessarily prohibitive for all projects identified at the start of the Green Gauge Programme.

5.1.2.4. Training and awareness barriers

The lack of management and staff not coming on board, emerged as a barrier in one of the responses. This site stated that 'The environmental on boarding of management and all other employees is essential.' This barrier could be in some way related to lack of buy-in which was discussed under organisational barriers.

5.1.2.5. Overall benefit

Whilst there were many key factors, both barriers and drivers, emerging from the responses to the questionnaire, it is clear that the Green Gauge Programme was seen as beneficial by the majority of participating sites. In fact, 77% of the respondents viewed the Green Gauge Programme as being beneficial in terms of achieving energy saving at their sites (See Figure 5.16).

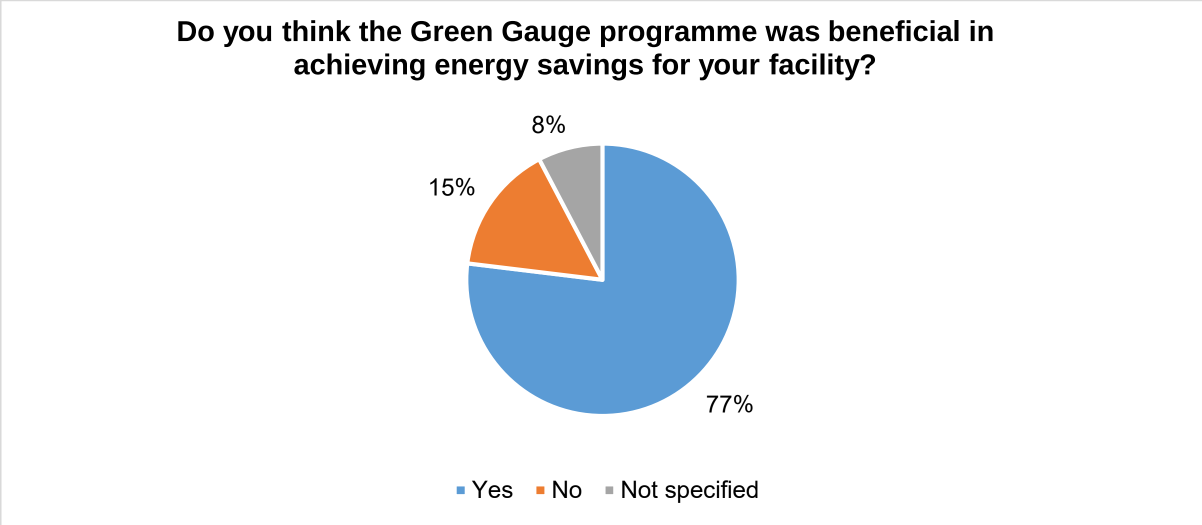


Figure 5.16: Responses to the question: Do you think the Green Gauge Programme was beneficial in achieving energy saving for your facility?

In addition, 100% of the respondents indicated that they would support a programme similar to the Green Gauge Programme in the future (See Figure 5.17).

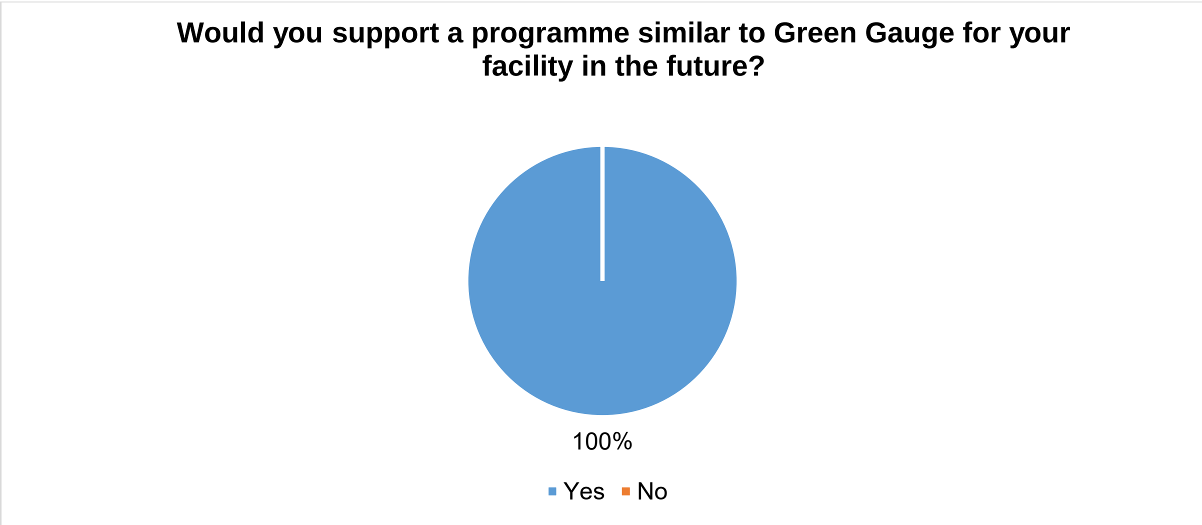


Figure 5.17: Responses to the question: Would you support a programme similar to Green Gauge for your facility in the future?

Although they would support a programme such as the Green Gauge Programme, many of the respondents make recommendations in areas for improvement. These are summarised below:

- stakeholders need to be properly engaged;
- there needs to be buy-in from senior management (i.e. sponsors that are incentivised);
- improvement should be measured and recognised;
- a fulltime resource should be appointed to coordinate and run the programme;
- on-boarding of management and all employees is important;
- the responsible resources must have the required technical expertise (i.e. the engineering or technical personnel as opposed to the SHE personnel);
- funding must be made available; and
- all costs to be incurred in a specific project should be identified upfront, including costs relating to maintenance.

5.2. The extent of energy efficiency applied at manufacturing facilities as part of AECI's Green Gauge Programme

In this section, the extent of energy efficiency realised through the Green Gauge Programme is examined. The intention is for this to provide insight into what can be realised in the broader manufacturing sector in South Africa and what this would entail in order for it to be realised (i.e. project types to be prioritised for implementation, etc.).

5.2.1. Summary of the outcome of the programme

Through the energy assessments, 293 energy efficiency measures were identified. Approximately 11% of the total potential saving was realised.

5.2.2. Technologies/project type implemented

Various technological interventions or project types were identified. These included control (controlling the pressure and set point temperature); equipment replacement (replacing motors with more efficient motors); switching off/reduction in hours (switching off equipment when not in use); lighting; HVAC (air conditioning), leak detection and repair/insulation; steam traps; VSDs (installation of variable speed drives); fuel switch; energy recovery; installation of new equipment; housekeeping (cleaning and optimising equipment); redesign; electricity generation; removal of redundant equipment and renewable energy opportunities.

The percentage of projects implemented by project type is depicted in Figure 5.18.

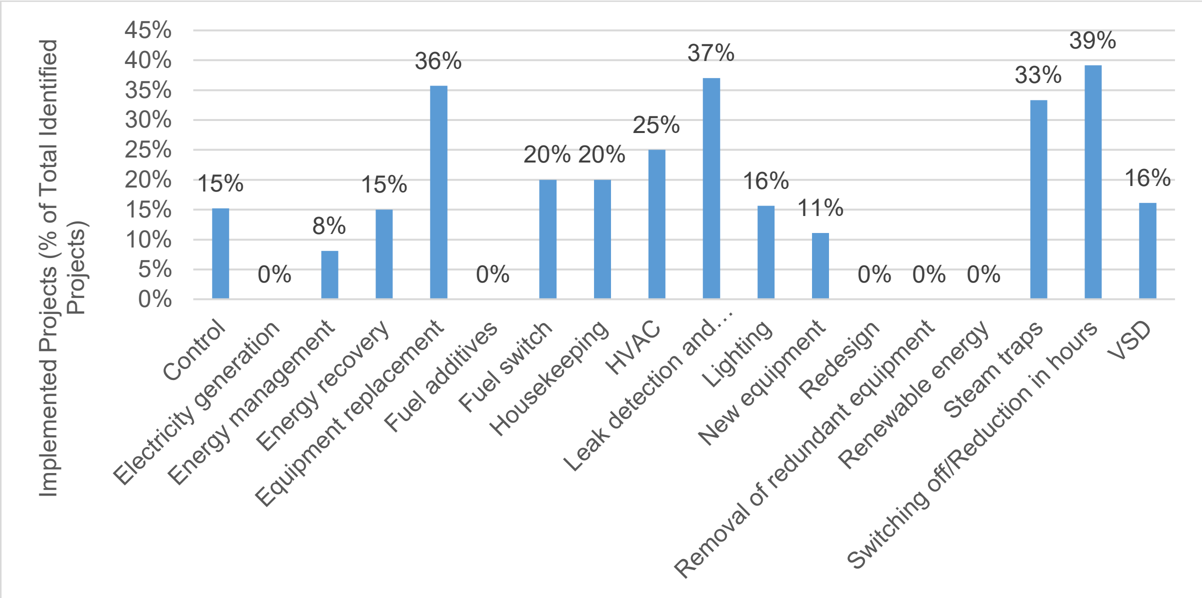


Figure 5.18: Percentage of projects implemented by project type

The project types with the highest percentage implemented were equipment replacement; leak detection and repair or insulation; steam traps and switching off equipment. These types of interventions had implementation percentages in excess of 30%. They would typically have a low or no capital cost and a short payback as seen in Figure 5.19.

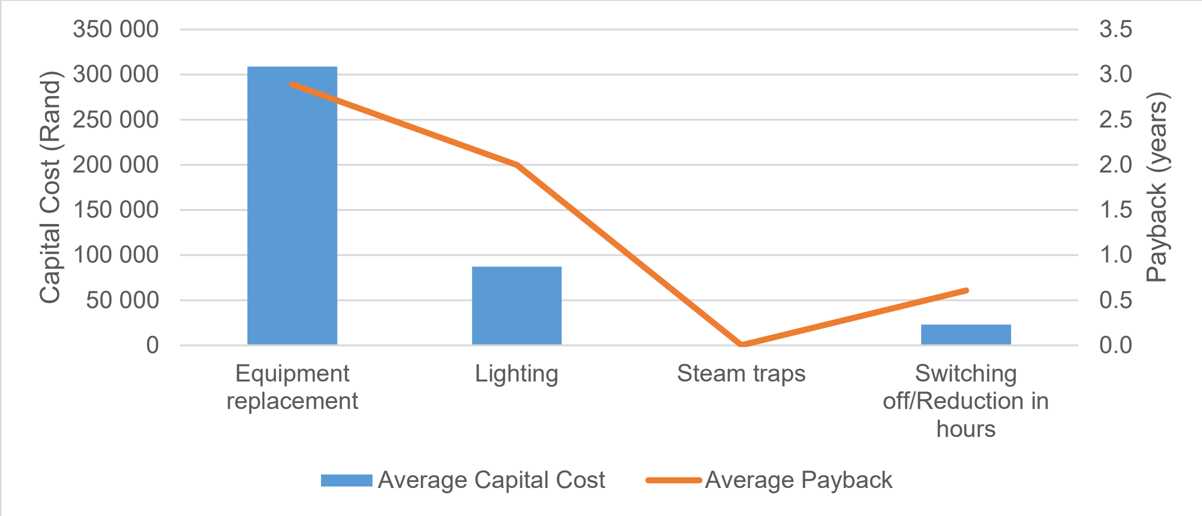


Figure 5.19: Average capital cost and average payback periods by project type for implemented projects

The abovementioned illustrates that the project types most implemented have a low capital cost and a short payback. The exception to this would be equipment replacement projects which have a higher capital cost and a longer payback than the other project types most implemented. In terms of equipment replacement projects, it should be noted that it appears as though many of these projects were planned prior to the Green Gauge Programme.

As such, energy efficiency measures that seem to have been successfully implemented are leak detection and repair, repair or application of insulation, repair of steam traps and switching off of equipment when not in use. This suggests that these project types could be considered for prioritisation in any energy efficiency programme in the manufacturing sector.

5.2.3. Low capital cost and short payback periods

In line with the theme of efficiency and cost saving that emerged as a key driver from the responses and literature review, the data were analysed in terms of the potential saving from low capital, low payback opportunities. Low capital was defined as projects with an estimated capital investment of less than R150,000 and low payback was identified as opportunities identified with a payback of less than 3 years – 109 (43%) of the 292 opportunities identified fell into the low capital cost, low payback period category and 22% of the opportunities in this category were implemented.

Figure 5.20 shows the low capital, low payback opportunities identified that were implemented and not implemented per type of intervention.

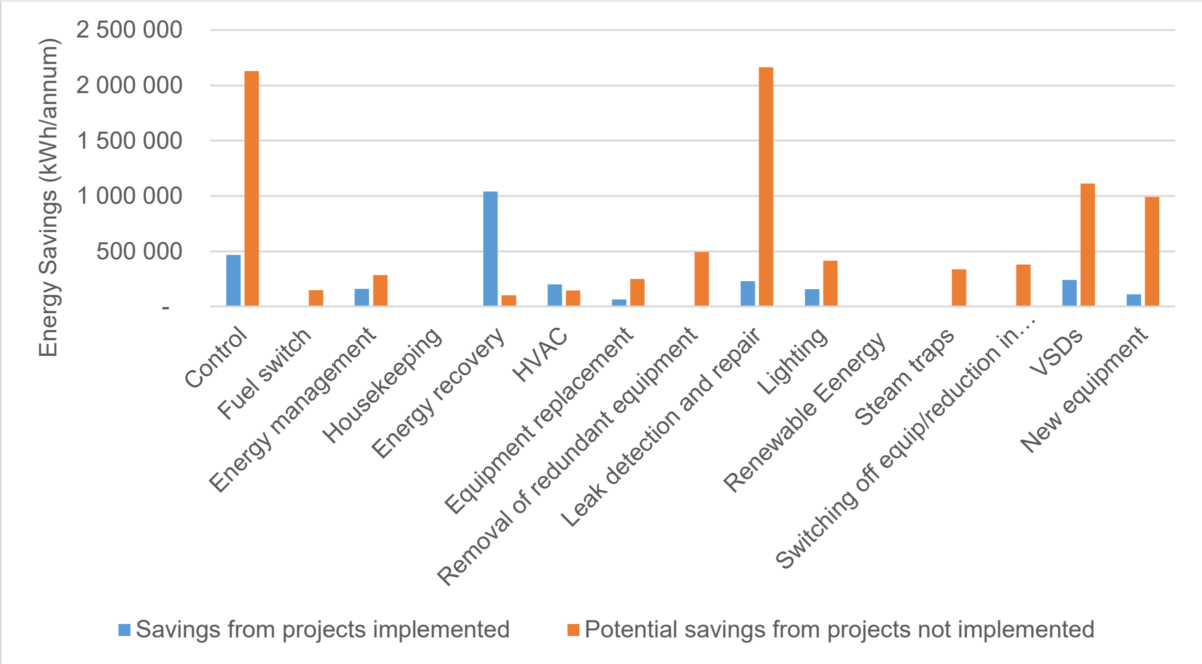


Figure 5.20: Energy savings from projects implemented and projects not implemented

The total potential saving from opportunities not implemented in the low capital cost, low payback category was approximately 9 million kWh per annum. The most significant potential for energy saving from this category was identified from the energy efficiency interventions of control, leak detection and repair, and variable speed drives. These types of interventions could realise potential energy savings of 1 million kWh and more. The potential saving from a few key interventions is discussed in further detail below:

5.2.3.1. Control intervention

Low payback low capital opportunities relating to control interventions were only implemented at one facility where a temperature control valve was installed limiting the return temperature of water to the hot water tank. The energy saving was estimated at 466,54 kWh per annum, with a low capital investment of R12,431 and a payback of 0.05 years. However, there were 15 opportunities relating to control interventions that were not implemented although the capital investment was less than R100,000 and payback less than 3 years. The potential energy saving from the 15 opportunities was estimated to be greater than 2 million kWh in energy savings per annum – 33% of the opportunities not implemented were from facilities that did not implement any opportunities due to organisational factors (buy-in and lack of resources), as well as the business focusing on other priorities such as compliance. The remaining 10 non-implemented opportunities were from 9 facilities representing on average 1 control opportunity per facility not implemented. Although in total the number of missed opportunities is high, if it is considered per facility, then the number of opportunities not implemented is low. However, there still remains a significant potential for energy saving from the 15 opportunities that were not implemented.

5.2.3.2. Leak detection and repair and insulation repair

18 opportunities were identified for this type of intervention, of which 7 were implemented. From the 11 opportunities that were not implemented, potential saving was estimated at approximately 2.2 million kWh per annum, and these 11 opportunities linked to 9 facilities. The opportunity with the highest potential saving concerned the steam distribution system where potential issues were identified with steam traps passing and areas where insulation was potentially damaged. It was recommended that the facility purchase an ultrasonic leak detector and thermal camera to conduct inspections and thereafter repair leaks and insulate damaged areas. The potential energy saving from this opportunity was estimated at approximately 700,000 kWh per annum. Figure 5.21 shows the energy saving from implemented and not implemented leak detection and repair opportunities.

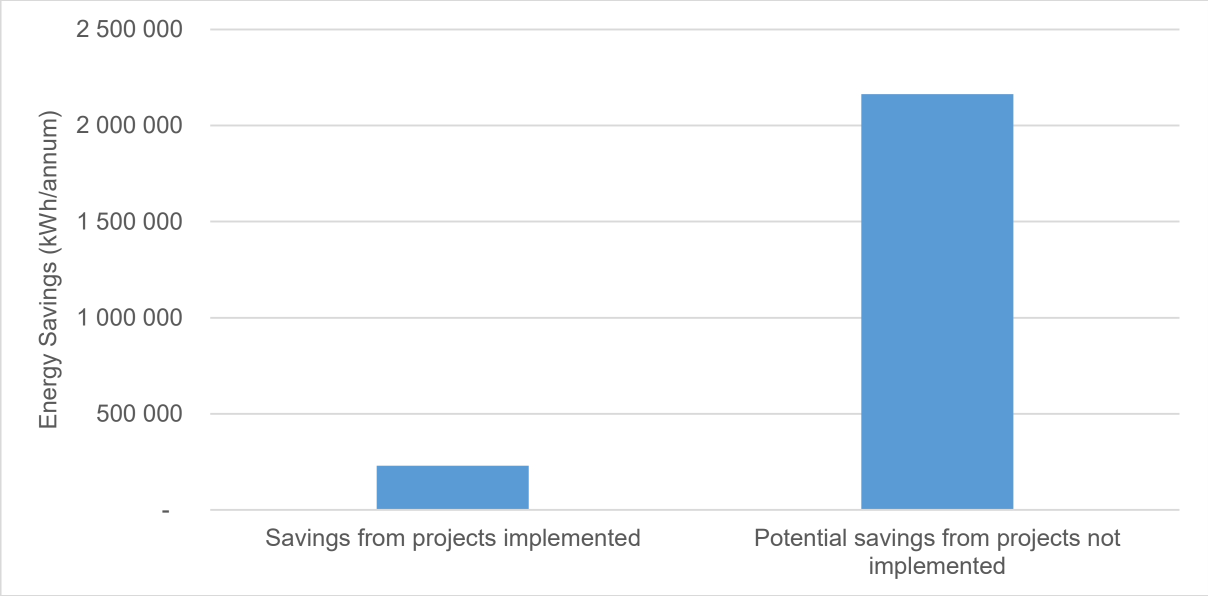


Figure 5.21: Leak detection and repair energy savings (implemented and not implemented opportunities)

5.2.3.3. VSDs

There were 12 VSD opportunities identified of which 5 were implemented. The 7 opportunities not implemented demonstrated potential energy savings of 1.1 million kWh. More than 70% of the VSD opportunities not implemented were linked to facilities that did not implement any opportunities or had a low implementation rate. This was due to barriers such as organisational factors (buy-in and lack of resources) and other business priorities (compliance and restructuring). Figure 5.22 shows the energy saving from implemented and not implemented VSD opportunities.

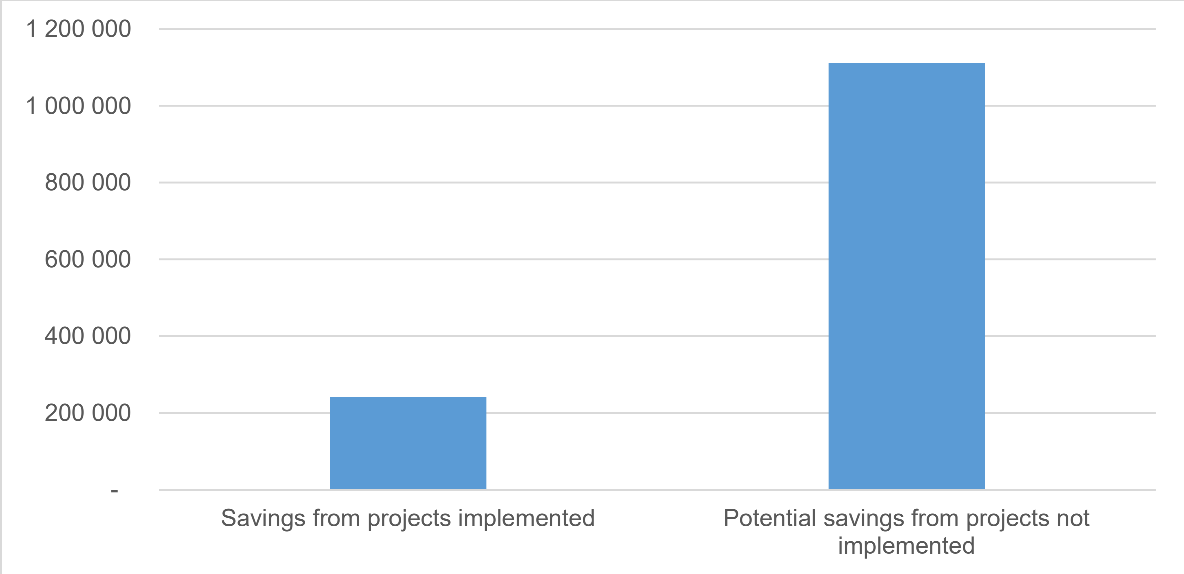


Figure 5.22: Energy savings from implementation of VSDs (implemented and not implemented opportunities)

5.2.3.4. Equipment replacement

Equipment replacement opportunities were implemented at four facilities:

One of the facilities had already started a programme of installing higher efficiency motors where possible – when existing motors failed – rather than re-winding the motors. The same facility also replaced its ageing refrigeration plant which expected to reduce peak loads from 320A to 220A due to improved efficiency.

Large compressors were replaced with smaller units at two facilities to match the smaller load requirements resulting in reduced energy losses. In addition, an aging cooling tower was replaced, as well as agitator motors with more efficient motors.

Six opportunities related to opportunities of low capital cost and low payback (less than R150,000 and less than 3 years payback) – however, these were not implemented at the facilities.

Four of the opportunities linked to facilities that did not implement any opportunities or had a low percentage of overall implemented opportunities due to organisational barriers (buy-in and lack of resources). It is not clear why the remaining 2 unimplemented opportunities from 2 facilities were not implemented. The untapped potential saving from low capital, low payback opportunities was estimated to be approximately 250,000 kWh per annum, representing 6% of the total opportunities identified (See Figure 5.23).

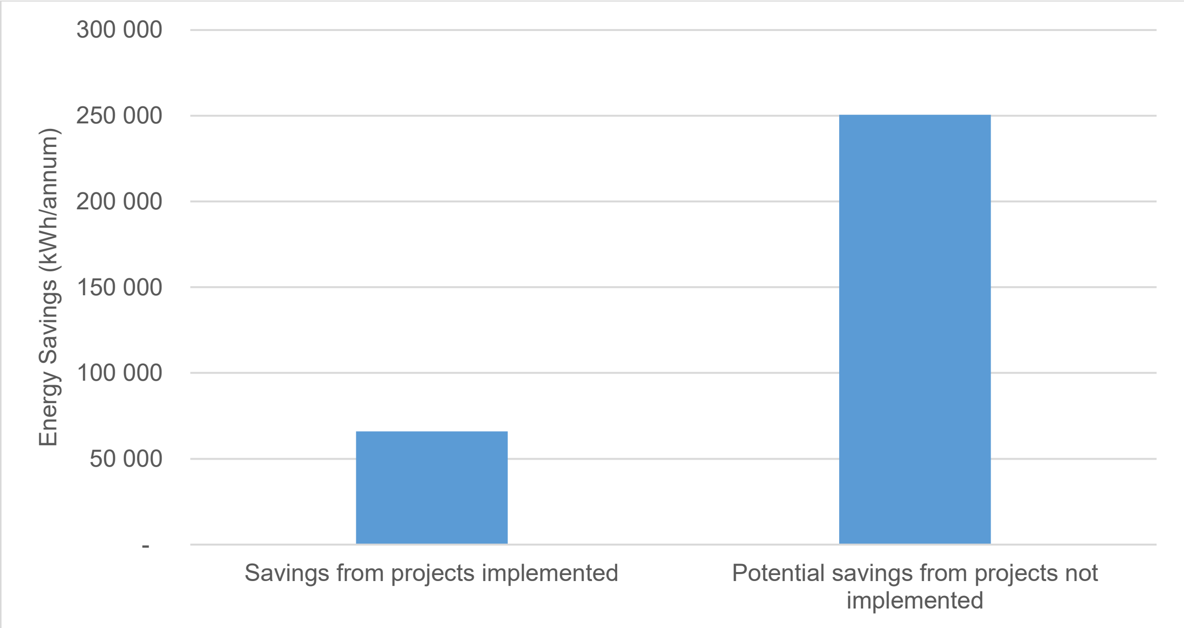


Figure 5.23: Implemented and not implemented energy savings for equipment replacement

5.2.4. No capital cost and no payback opportunities

A large number of opportunities – 28% of those identified – did not require any capital investment. However, only 23% of the opportunities in this category were implemented at facilities, equating to potential energy saving of approximately 11.3 million kWh per annum that was not implemented. Figure 5.24 shows the potential energy saving for the most significant implemented and not implemented opportunities for the various types of energy efficiency measures requiring no capital investment.

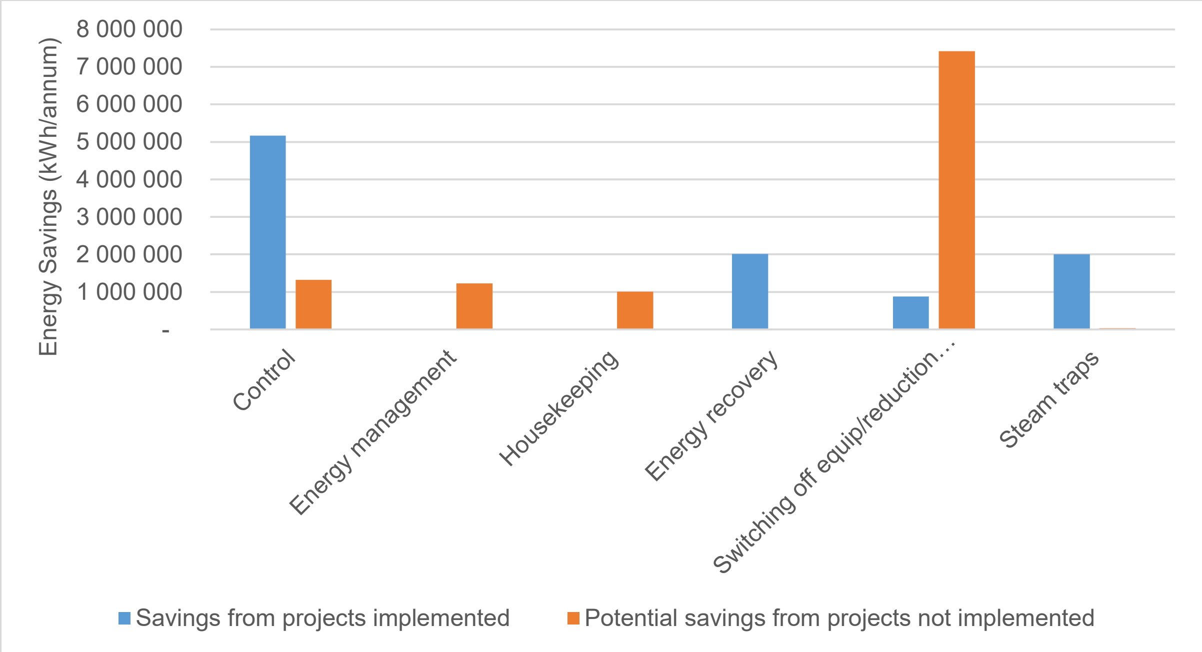


Figure 5.24: Implemented and not implemented energy savings per type of opportunity requiring no capital investment

5.2.4.1. Control

Control interventions included measures such as automatic control of the blow-down valve, optimisation of blow offs, reducing pressure and temperature, controlling blow-downs, optimise steam usage and adjusting total dissolved solids set point. Although a significant amount of energy saving was harnessed from control interventions, there still remains 16 opportunities not implemented (5 were implemented) equating to 1.3 million kWh per annum of potential energy saving. These opportunities were spread across 8 manufacturing facilities, and 50% of the opportunities linked to those facilities that either did not implement any opportunities or implemented a low number of opportunities due to organisational barriers (buy-in, lack of resources and other business priorities). It is unclear why the remaining facilities did not implement the opportunities. There is, however, certainly an opportunity for the facilities to explore implementation in the future.

5.2.4.2. Energy management

The energy management opportunities also included many opportunities that were not implemented – more than 90% of the opportunities remain unharnessed equivalent to energy savings of approximately 1.2 million kWh per annum. Energy management included measures such as metering and targeting, LPG optimisation, plant optimisation, reducing electrical maximum demand, steam optimisation, data management and energy management services. Approximately 45 % of the non-implemented opportunities are linked to facilities that experienced organisational barriers such as other business priorities, poor buy-in and lack of resources. It remains unclear why the remaining 65% of the opportunities were not implemented.

5.2.4.3. Housekeeping

The housekeeping type of interventions included undertaking cleaning regimes in the boiler house. Only 2 opportunities remained not implemented. However, these opportunities became non-relevant with the fuel switching projects at the 2 facilities in question.

5.2.4.4. Switching off equipment

This type of opportunity included turning off pumps, blowers, steam when the plant is down, running pumps on a campaign basis, optimising use of machines, switching lights off during the day, turning off air conditioning when not required, turning off circulation pump during summer, and stop using compressed air for cleaning. The potential saving from opportunities not implemented were approximately 7.4 million kWh per annum, representing the most potential opportunity for energy saving in the category of no capital investment required – 40% of the non-implemented opportunities, linked to facilities that experienced organisational barriers, and the remaining 60% equated to one opportunity per facility not being implemented in this category.

5.2.4.5. Energy recovery and steam traps

The opportunity types energy recovery and steam traps show good performance in terms of opportunities implemented in the category no capital investment. Majority of the opportunities were implemented amounting to energy saving realised of approximately 4 million kWh. These opportunities also linked back to 2 facilities both of which demonstrated good overall rates (greater than 30%) of implementation of opportunities.

5.2.5. Low capital cost and high payback opportunities

The third category of opportunities where a significant number of opportunities was identified, was under the low capital cost (less than R150,000, high payback – greater than 4 years – category). This category linked to the low cost opportunity driver which emerged as a factor towards energy efficiency from some of the responses to the questionnaire. However, from the data obtained from the facilities, only 12% of the opportunities in this category were implemented. The potential saving that could be estimated from this category was 332,863 kWh per annum. Some of the key findings are discussed below.

5.2.5.1. Control and energy management

All the opportunities relating to control and energy management (33% of the opportunities in this category) were not implemented in the low capital cost, high payback category. The energy saving could not be estimated for all the opportunities identified and this may have been a barrier to implementation.

5.2.5.2. Lighting

Thirteen per cent (13%) of the lighting opportunities were implemented in the category of low capital cost, high payback. The potential energy saving from the remaining unimplemented opportunities was estimated at approximately 120,000 kWh per annum spread across 6 facilities.

5.2.5.3. VSDs

Approximately 40% of the VSD opportunities were implemented at facilities realising 95,041 kWh in saving. The potential saving from the remaining VSD opportunities not implemented was estimated at approximately 60,000 kWh per annum and linked to 4 facilities, 60% of which did not implement any opportunities and had a low implementation rate due to organisational barriers (such as buy-in and restructuring of the business).

According to the Draft Post 2015 National Energy Efficiency Strategy (DoE, 2016:10) South Africa's energy consumption was approximately 2 236 PJ in 2012. The industrial sector in South Africa makes up about 35% of the total final energy consumption (Singh & Lalk, 2016:287). This amounts to 782.6 PJ in energy consumption for the South African industrial sector. Extrapolating the energy saving from low or no capital investment (less than R150,000) and low payback projects (less than 3 years) from AECI's Green Gauge Programme to the South African Industrial sector, the potential saving from implementing low capital investment projects is estimated to be 75.8 PJ or 21,043 816 MWh. This is equivalent to approximately 9.7% of South Africa's total electricity consumption representing a significant amount of energy saving if such a programme would focus only on low or no capital investment and low payback energy efficiency projects in the South African industrial sector.

5.3. Model for future programmes

AECIs Green Gauge Programme provides a platform for the manufacturing sector to learn from and implement similar programmes at their facilities. This section provides recommendations to guide manufacturing facilities effectively implement an energy efficiency programme.

From analysis of the data and the responses to the questionnaire, it is clear that the energy efficiency component of the Green Gauge Programme was beneficial to AECI manufacturing facilities in terms of realising energy saving, as well as financial and environmental benefits. However, many areas of improvement, as well as good practices were highlighted that were used to develop a traffic light model that could be used by other manufacturing facilities wishing to embark on a similar programme.

A traffic light system was developed based on the responses from the questionnaire and analysis of the data from the Green Gauge Programme. More than 80% of the energy efficiency measures implemented at the manufacturing facilities fell into the low or no capital cost category, therefore one of the key recommendations would be to prioritise these opportunities. In some cases projects with a high payback and low capital cost were implemented; therefore the suggestion is to consider if payback is an important criteria for decision-making.

A large part of the recommendations in the traffic light system was informed by the themes emerging from the responses to the questionnaire from individuals that were closely involved with the Green Gauge Programme. The key emerging driver and barrier themes from the responses to the questionnaires are depicted in Figure 5.25.

Figure 5.25: Key drivers and barriers from responses to questionnaire

Figure 5.26 is the traffic light system demonstrating the do's, considerations and don'ts to take into account when developing a strategy and embarking on an energy efficiency programme.

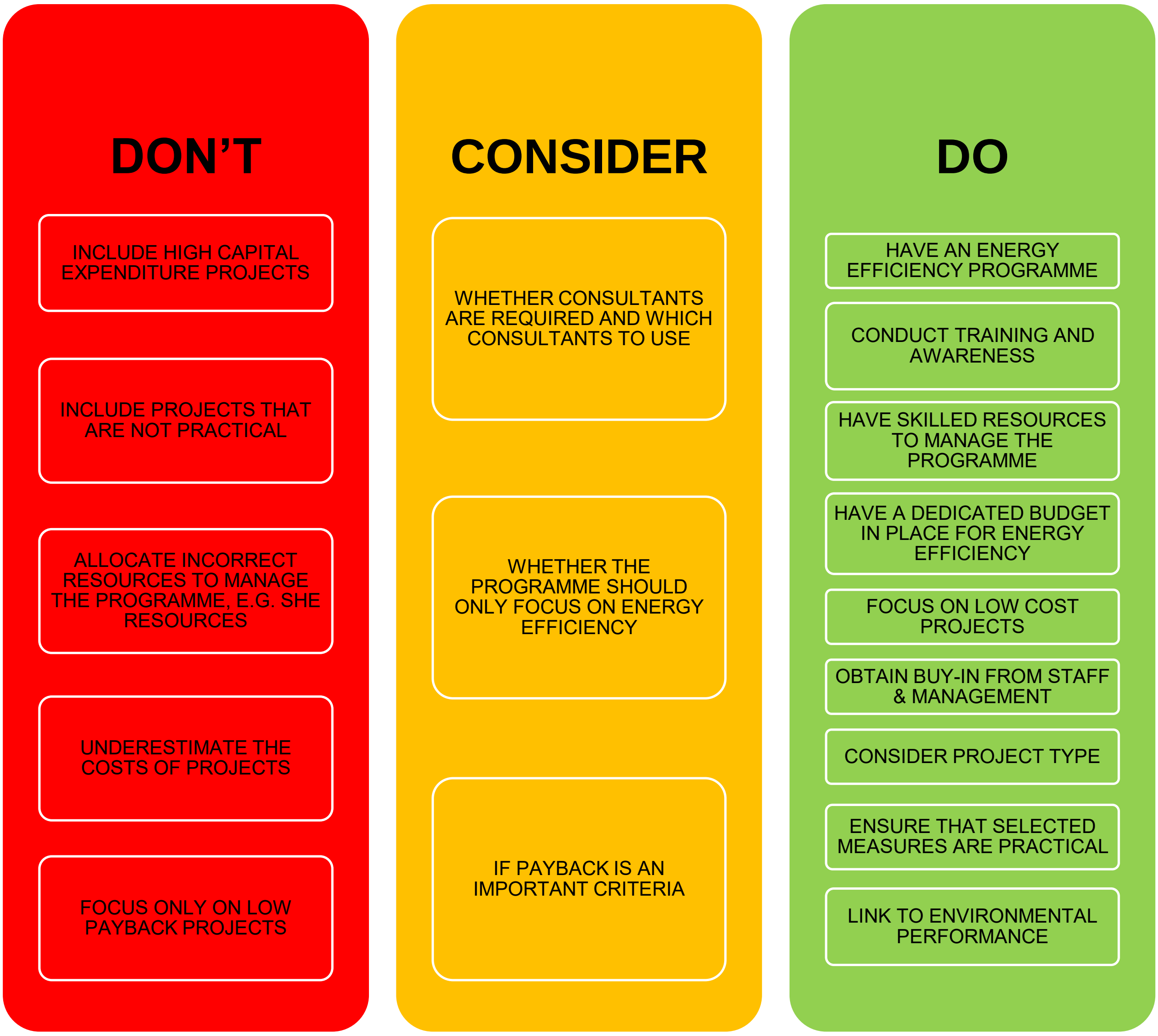


Figure 5.26: Traffic light system

To enable companies to practically implement the recommendations from the traffic light system, a step by step model was developed (See Figure 5.27).

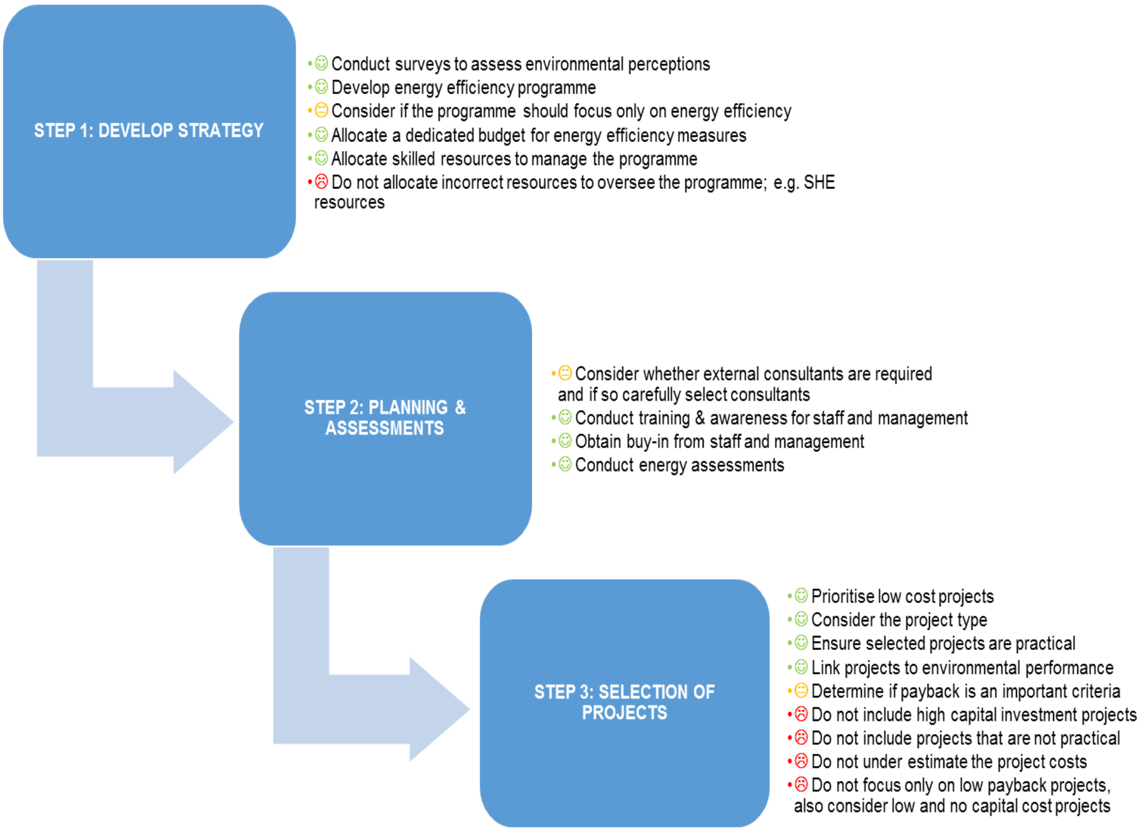


Figure 5.27: Steps to follow in rolling out an Energy Efficiency Programme

The abovementioned model outlines the key steps to follow in rolling out an energy efficiency programme incorporating the key considerations from the traffic light system (Figure 5.26) informed by the results of AECI's Green Gauge Energy Efficiency Programme. A vital aspect at the start of the programme is to conduct surveys to access perceptions on environmental matters in order to gauge employees and managers commitment to implementing energy efficiency measures. Other key aspects to incorporate in the strategy are dedicated resources and the right resources, allocation of a budget and the development of the programme.

Step 2 of the model focuses on training and awareness, consideration of the use of external consultants, obtaining buy-in from staff and management – all of which emerged as key factors from the responses to the questionnaire. Conducting energy assessments forms the last phase of step 2.

Step 3 considers key criteria in the selection of energy efficiency measures also informed by key factors from the responses to the questionnaire and is also informed by the outcomes of the data analysis.

Other steps such as monitoring and verification and reporting would typically follow step 3; however this study did not focus on those aspects, so detail on those areas was not included in the abovementioned model.

The types of projects to be selected are an important consideration as part of Step 3. Table 5.3 provides options of the types of projects to be selected in terms of the highest percentage implemented (top 10 measures), average capital investment and average payback of energy efficiency measures that were implemented at AECI manufacturing sites from the Green Gauge Programme.

Table 5.3: Top 10 implemented projects with average capital investment and payback:

Type of energy efficiency measure	% Implemented	Average capital investment	Average payback (years)
Switching off/reduction in hours	39%	R23,000	0.6
Leak detection and repair/insulation repair	37%	R86,102	0.8
Equipment replacement	36%	R166,757	2.9
Steam traps	33%	R 0	0
Heating, ventilation, air conditioning (HVAC)	25%	R130,000	0.8
Housekeeping	20%	R20,000	3.0

Type of energy efficiency measure	% Implemented	Average capital investment	Average payback (years)
Variable speed drives	16%	R63,916	2.5
Control	15%	R30,347	0.1
Energy Recovery	15%	R83,333	0.8
Lighting	15%	R86,942	2

The list of the types of projects in the abovementioned table provides a range of options for manufacturing companies which are aligned to the efficiency/cost saving and low cost drivers. All of the project types reflect low average capital cost investments and low payback periods which makes them attractive to companies that have a constrained budget and are focused on cost saving.

It is vital that companies wishing to embark on an energy efficiency programme do so by leveraging on the experiences that other companies have had. The model provided in this section provides insight and perspectives on the challenges and successes experienced by the 16 manufacturing facilities that partook in AECI's Green Gauge Programme. Key insights from the questionnaire can support the development of a well-informed strategy and insights from the data analysis can assist companies in optimal selection of energy efficiency projects.

Chapter 6: Conclusion and Recommendations

This chapter summarises the key findings and insights of this study that can be used by other South African industries and potentially global industries to inform implementation of their own energy efficiency programmes. A summary of key recommendations relating to the extent or potential for energy saving per technology, cost criteria for implementation of measures and insights from programme managers of AECI's Green Gauge programme is provided which will inform and enable companies to formulate strategies and plans for their own energy efficiency programmes. In addition, the limitations of the study are discussed and future research opportunities in this area are highlighted.

6.1. Key findings of the study

In conducting this study an understanding of the implementation of energy efficiency programmes in industry has been formed by addressing the research objectives set out for the study.

6.1.1. Connecting the key drivers and barriers between the literature review and practice

An in-depth literature review was conducted exploring the drivers and barriers towards implementation of energy efficiency interventions globally and in South Africa covering both developed countries, as well as emerging economies. The key drivers and barriers identified from the literature review are summarised in Table 6.1.

Table 6.1: Key drivers and barriers identified from literature review

Key Drivers	Key Barriers
Efficiency (financial benefits/cost saving)	Access to capital
Policy	Other priorities requiring capital investment

Key Drivers	Key Barriers
Energy pricing	Lack of technical skills
Economic development and technological progress	Technological barriers
Market pressure	Environmental management systems
Organisational	Behavioural and awareness

While some drivers and barriers applied only to emerging economies, there were common drivers and barriers to both developed and developing countries. Factors such as other priorities requiring capital investment, lack of technical skills and technological barriers were featured more prominently as key issues in developing countries. In South Africa (eThekwini manufacturing sector) the most significant factor inhibiting implementation of energy efficiency measures was found to be cost-related (Singh & Lalk, 2016:301).

The key themes, in terms of drivers and barriers, emerging from the questionnaire sent out to individuals involved in the Green Gauge Programme were closely aligned with the key drivers and barriers identified from the literature review. Some of the exceptions were:

- Drivers: reduce waste and environmental
- Barriers: infrastructure

However, when correlating the qualitative data (questionnaire responses) against the quantitative data (5 implemented projects), the driver 'reduce waste' was only identified as a driver at 3 of the 16 sites. Infrastructural barriers were identified as a barrier at 5 of the 16 sites. However, some of these sites still implemented a significant percentage of identified projects, which indicate that infrastructural barriers were not necessarily a key barrier. The environmental theme emerged as a key theme from the responses with 6 of them highlighting it as a driver. However, this may not be a stand-alone driver as other key drivers were also associated with the sites that identified environment as a driver.

Efficiency/cost saving emerged as the dominant driver from the responses, with this driver emerging in more than 60% of the responses. This aligns well with efficiency also emerging as the key driver from the literature review conducted. Another predominant driver emerging from the responses was low cost opportunities identified as a driver from more than 40% of the responses. This aligns with low capital and low payback opportunities being favoured, with 22% of the projects in this category having been implemented at manufacturing facilities in the Green Gauge Programme.

One of the key drivers emerging from the literature review that was not highlighted in the responses to the questionnaire was policy. This was possibly not highlighted as the South African energy policy landscape was not mature during the time when the Green Gauge Programme was implemented. This driver emerged as a key driver in the literature pertaining to mostly developed countries.

Other key drivers not identified in the responses were energy pricing and market pressure, which emerged as key drivers in the literature review. Possible reasons are that South Africa's electricity prices are still amongst the lowest in the world and market pressure is not yet a driver, but increasingly becoming one in developing countries.

Key barriers emerging from the questionnaire responses were organisational (lack of resources and buy-in), as well as capital and access to capital. An analysis of the quantitative data corroborates with the identified theme of capital and access to capital from the responses as most of the implemented projects had a capital cost of less than R100,000 (Figure 5.7, page 141), a clear indication that projects with a low upfront cost were favoured. Interestingly, there were several projects implemented with a low capital cost, but a payback period in excess of 3 years, indicating that low capital cost plays a greater role than payback period. Access to capital also emerged as a predominant barrier from the literature review.

Organisational challenges, such as resource constraints and lack of buy-in, emerged as a key barrier from the questionnaire responses, with about 40% of the responses highlighting this barrier and the majority of these sites implementing less than 15 % of the opportunities identified (Figure 5.4, page 146). However, lack of buy-in appeared to be more of a barrier than lack of resources. Lack of resources was also identified in the literature review as a key barrier, predominantly in developing countries.

While there were several barriers and drivers emerging from the responses, the majority of the respondents (77%) viewed the Green Gauge Programme as being beneficial in terms of achieving energy saving at their sites and 100% of the respondents indicated they would support a similar programme in the future.

6.1.2 Connecting the extent of energy efficiency applied in the manufacturing sector between the literature review and practice

A detailed literature review was conducted across various countries and sectors within the industrial sector covering both developed and developing countries. The potential for energy saving across several regions and countries was reviewed with the following outcomes depicted in Table 6.2:

Table 6.2: Potential for energy savings per region or country

Country/region	**Sector**	**Potential for energy savings**
European Union	Industrial sector	10 – 20%
European Union	SMEs (industrial sector)	>25%
Italy	Paper sector	16.2%
Italy	Glass sector	8.8%
India	Manufacturing sector	14.8%
Turkey	SMEs (industrial sector)	50-61%
China	Manufacturing sector	57%

Global	Steel	9% (industrialised countries) – 30% (developing countries)
Global	Aluminium	12% (industrialised countries) – 23% (developing countries)
Global	Cement	20% (industrialised countries) – 25% (developing countries)
Global	Paper	18% (industrialised countries) – 28% (developing countries)
Global	Plastics	9% (industrialised countries) – 27% (developing countries)

The potential for energy saving was measured against different metrics such as energy demand or against another country's specific energy consumption. Therefore it did not make sense to undertake a comparison between the potential for energy saving in the literature and practice, i.e. AECI's Green Gauge Programme.

However, a comparison was possible between the actual saving from energy efficiency programmes from the literature review and AECI's Green Gauge Programme. A summary of the actual saving from programmes reviewed in the literature review is indicated in Table 6.3.

Table 6.3: Saving achieved from programmes in literature review

Sector	**Saving**
European Union SMEs (Industrial sector)	5%
Dutch Manufacturing industry	1.9% (electricity) 2.6% (fuels & heat)
Malaysian ISO 14001 industries	0.3%

Colombia Chemical & Automotive industries	Greater than 85%
South African Industrial Sector	34.3%

From analysis of the analytical data, the energy savings realised from AECI's Green Gauge Programme was approximately 11% of the total potential saving identified which is comparable with the saving achieved that was observed in the literature review.

The most implemented energy saving opportunities were then reviewed as part of the literature review with the most commonly implemented opportunities summarised in Table 6.4.

Table 6.4: Commonly implemented energy saving technologies from the literature review

Implemented energy saving technology	**Sector**
Utilise high efficiency lamps and/or ballasts	Primary metal, textiles and plastics manufacturing (IAC and ITA databases)
Eliminate leaks in inert gas and compressed air lines/valves	
Install compressor air intakes in coolest locations	
Use most efficient type of electric motors	
Utilise energy-efficient belts and other	
Utilise energy efficient belts and other improved mechanisms	
Insulate bare equipment	
Control system for shut down of machines in off-peak periods	European manufacturing sector focusing on Slovenia and Spain
Speed regulation	
Compressed air contracting	
Highly efficient pumps	
Low-temperature joining processes	
Energy recovery	
Bi-/Tri-generation	

Implemented energy saving technology	**Sector**
Waste material for energy	
Variable speed drives	Global industrial sector, including manufacturing, agriculture, mining and construction
Energy saving through leak prevention in air compressors	
Use of high efficient electric motors	
Energy saving realised from pressure drop	
Energy saving from installation of economiser	
Lighting initiatives	National Cleaner Production Centre South Africa (data from 23 case studies from SA manufacturing sector)
Compressed air system and steam system leak detection and repair	
Optimising steam system, fan system, production, compressors, chillers, compressed air, air conditioning	
Insulation	
Switching off equipment when not in use	
Energy management and awareness	
Equipment retrofitting or replacement	
Fuel switching	
Operational control improvement	
Maintenance programme	
Heat and energy recovery	

From the analysis of the quantitative data from AECI's Green Gauge Programme, the top 10 implemented projects are reflected in Table 6.5.

Table 6.5: Top 10 implemented projects from AECI's Green Gauge programme

Switching off/reduction in hours
Leak detection and repair/insulation repair
Equipment replacement
Steam traps
Heating, ventilation, air conditioning (HVAC)
Housekeeping

Variable speed drives
Control
Energy Recovery
Lighting

The highest implemented projects from AECIs Green Gauge Programme are very closely aligned with commonly implemented opportunities implemented from the literature review as shown in Table 2.1 on page 27.

The projects that were the highest implemented from the Green Gauge Programme were typically projects with a low or no capital investment and short payback period. The average capital investment for the projects implemented in AECI's Green Gauge Programme ranged from R0 to approximately R167,000 and the average payback period ranged between 0 and 3 years – a strong indication that projects with low or no capital cost and short payback periods are favoured. Upon review of the National Cleaner Production Centre's Industrial Energy Efficiency Programme case studies, it was also clear that companies did not invest a significant amount of capital in energy efficiency projects. The capital investment was disclosed per company, not per energy efficiency project and ranged from R34,500 to R3.3 million per company (refer to Table 4.1 on pages 124-125). The payback period ranged from 0.01 to 4 years, also closely aligning with the average payback period from AECI's Green Gauge Programme of between 0 and 3 years.

Extrapolating the savings from low or no capital investment projects from AECI's Green Gauge Programme to the South African industrial sector, it is estimated that the potential savings would be 21,393,268 MWh. This represents approximately 10% of South Africa's total electricity consumption if energy efficiency programmes focused only on low or no cost capital investment projects.

Energy management systems were reviewed as part of the literature review looking at the various types of energy management systems employed globally. Case studies from the National Cleaner Production Centre (NCPC) South Africa were reviewed and it was found that more than 50% of industries participating in the NCPC-SA had implemented an energy management system using the ISO 50001 energy management standard mostly through funding from the United Nations International Development Organisation. None of the AECI manufacturing companies that participated in the Green Gauge Programme implemented an energy management system. It may, however, be a consideration with future programmes especially if energy regulations are awarded greater focus in the future.

6.2 Overall summary

From analysis of the quantitative and qualitative data it is clear that the energy efficiency component of AECI's Green Gauge Programme was effective and beneficial in realising energy saving, as well as financial and environmental benefits. In addition, there was close alignment between the key themes identified between the literature review and practice.

6.3 Recommendations

This study will enable other AECI businesses and manufacturing companies to draw on the findings and insights from AECI's Green Gauge Programme to incorporate key considerations in the strategy and planning phases of their own energy efficiency programmes. Recommendations and areas of improvement are summarised below:

A traffic light system was developed informed from themes emerging from the responses to the questionnaire and analysis of the quantitative data (see Figure 5.26: page 166). The traffic light system included three categories to be considered by companies when embarking on an energy efficiency programme: Don'ts, Considerations and Do's.

A model providing step-by-step recommendations was then developed and is proposed to companies to enable companies to practically implement their energy efficiency programmes (see Figure 5.27, page 167).One of the key steps of the model is selection of projects – a list of the types of projects is recommended in Table 5.3 on pages 168-169 with corresponding average capital investment and payback periods.

6.4 Limitations

The study focused on energy efficiency within the manufacturing sector using AECI's Green Gauge Programme at 16 manufacturing sites as a case study. Other AECI manufacturing sites may have implemented energy efficiency measures, but were excluded from the study as they did not partake in the Green Gauge Programme. The findings of this study are limited to the manufacturing sector and can be applied to the global and local manufacturing sector, but are more relevant to the South African manufacturing sector.

6.5 Future research opportunities

There is limited research on energy efficiency in the South African manufacturing and industrial sector although there were various energy efficiency programmes rolled out. A recommendation for future research would be to evaluate the effectiveness of energy efficiency programmes in the South African industrial sector and develop a model to ensure such programmes are sustainable.

References

Abdelaziz E.A., Saidur R. & Mekhilef, S. 2011. A review on energy saving strategies in industrial sector. *Renewable and Sustainable Energy Reviews*, 15: 150-168.

ABB. 2016. Available on the website at: http://us-cdn.creamermedia.co.za/assets/articles/attachments/66099_africa_.pdf

AECI. 2019. Profile and strategy, available at: https://www.aeciworld.com/about-profile-strategy.php. Accessed on 07 January 2019.

Apeaning, R.W. & Thollander P. 2013. Barriers to and driving forces for industrial energy efficiency improvements in African industries: a case study of Ghana's largest industrial area. *Journal of Cleaner Production*, 53:204–213.

Apostolos, F., Alexios, P., Georgios, P., Panagiotis, S. & George, C. 2013. Energy efficiency in manufacturing processes: a critical review. *SciVerse Science Direct,* 628-633.

Arnoldy, M. 2018. Energy industry in need of efficiency intervention. *Engineering News.* 13 November 2018. Available at: <http://www.engineeringnews.co.za/article/energy-industry-in-need-of-efficiency-intervention-2018-11-13/rep_id:4136> (Accessed 3 June 2018).

Aurini, J.D., Heath, M. & Howells, S. 2016. *The how to of qualitative research*. London: SAGE.

Aye, G.C., Gupta, R. & Wanke, P. 2018. Energy efficiency drivers in South Africa: 1965-2014. *Energy Efficiency*, 11:1465-1482.

Azadeh, A., Amalnick, M.S., Chaderi, S.F. & Asadzadeh, S.M. 2007. An integrated DEA PCA numerical taxonomy approach for energy efficiency assessment and consumption optimization in energy intensive manufacturing sectors*. Energy Policy,* 35:3792-3806.

Blass, V., Corbett. C.J., Delmas, M.A. & Muthulingam, S. 2014. Top management and the adoption of energy efficiency practices: Evidence from small- and medium-sized manufacturing firms in the US. *Energy,* 65:560-571.

Bryman, A. & Bell, E. 2015. *Business research methods.* Fourth Edition. London: Oxford University Press. Fourth Edition. Pages 641-659.

Bunse, K., Vodicka, M., Schönsleben, P., Brülhart, M. & Ernst, F.O. 2011. Integrating energy efficiency performance in production management – gap analysis between industrial needs and scientific literature. *Journal of Cleaner Production,* 19(6–7):667-679.

Businge, C.N., Bazzocchi, F., Gobbi, E. & Zagano, C. 2018. Energy efficiency for a sustainable industry: energy saving potential for Italian manufacturing sectors and impact of energy efficiency measures on economic performance and competitiveness of enterprises. *Industrial Efficiency*, 1-10.

Cagno, E. & Trianni, A. 2012. Analysis of the most effective energy efficient opportunities in manufacturing primary metals, plastics, and textiles small- and medium-sized enterprises. *Journal of Energy Resources Technology,* 134(2)1-9.

Cagno, E. & Trianni, A. 2013. Exploring drivers for energy efficiency within small- and medium-sized enterprises: First evidences from Italian manufacturing enterprises. *Applied Energy,* 104:276-285).

Cantore, N. 2017. Factors affecting the adoption of energy efficiency in the manufacturing sector of developing countries*. Energy Efficiency,* 10:743-752.

CDP. 2018. *Our Vision and Mission.* Available at: <https://www.cdp.net/en/info/about-us> (Accessed 12 October 2018).

Institute of Directors of Southern Africa. 2016. *King Report on Governance for South Africa 2016*. Available at: https://www.adams.africa/wp-content/uploads/2016/11/King-IV-Report.pdf (Accessed 29 January 2019).

DOE. 2015a. *SME guide to energy efficiency*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/417410/DECC_advice_guide.pdf. (Accessed 30 July 2019).

DoE. 2015b. *Energy statistics, energy balances.* Available at: http://www.energy.gov.za/files/energyStats_frame.html. (Accessed 30 July 2019).

Dos Santos. 2017. *The energy efficiency guide.* Nedbank, Carbon Trust and NBI. Available at: https://www.nedbank.co.za/content/dam/nedbank/site-assets/AboutUs/Sustainability/Supporting%20Documents/10073FAWEnergyEfficiencyGuide.pdf (Accessed 01 January 2019).

Dowell, G.W.S. & Muthulingam, S. 2017. *Will firms go green if it pays? The Impact of Disruption, Cost, External Factors on the Adoption of Environmental Initiatives*. Samuel Curtis Johnson, Graduate School of Management, Cornell University, Ithaca, New York, U.S.A. 1287-1288.

Fargani, H, Cheung, W.M. & Hasan, R. 2016. *An empirical analysis of the factors that support the drivers of sustainable manufacturing. Procedia CIRP* 56: 491-495.

Fernando, Y. & Hor, W.L. 2017. Impacts of energy management practices on energy efficiency and carbon emissions reduction: A survey of Malaysian manufacturing firms. *Resources, Conservation and Recycling*, 126:62-73.

Fresner, J., Morea, F., Kremm, C., Uson, A. & Tomasi, F. 2017. Energy efficiency in small and medium enterprises: Lessons learned from 280 energy audits across Europe. *Journal of Cleaner Production,* 142:1650-1660.

Gouws, P.A., Brent, A.C. & Pierce, W.T. 2012. The contribution of energy efficiency towards the success of industrial organisations in South Africa. *The South African Journal of Industrial Engineering,* 57-65.

Global Power Prices. 2018. Available at: https://businesstech.co.za/news/wp-content/uploads/2019/03/Global-Power-prices.png. (Accessed 29 June 2019).

Gutowski, T.G., Allwood, J.M., Herrmann, C. & Sahni, S. 2013. A global assessment of manufacturing: Economic development, energy use, carbon emissions, and the potential for energy efficiency and materials recycling. *Annual Review of Environment and Resources,* 38:81-106.

Hallowes D. 2011. *Toxic futures: South Africa in the crises of energy, Environment and Capital.*

Harding, J. 2013. *Qualitative data analysis from start to finish*. Thousand Oaks, California: SAGE.

Hochman, G. & Timilsina, G.R. 2017. Energy efficiency barriers in commercial and industrial firms in Ukraine: An empirical analysis. Department of Agricultural, Food, and Resource Economics. *Energy Economics*, 63:22–30.

Hrovatin, N., Dolsak, N. & Zoric J. 2016. Factors impacting investment in energy efficiency and clean technologies: empirical evidence from Slovenian manufacturing firms. *Journal of Cleaner Production,* 127: 475–486.

Huang, Y., Hsu, J. & Sun, L. 2017. A study of energy efficiency and mitigation of carbon emission: Implication of decomposing energy intensity of manufacturing sector in Taiwan. *International Journal of Energy Economics and Policy,* 7(2):26-33.

Internal AECI Document. 2011a. [Internal Departmental Document, Opportunities Database, used by AECI].

Internal AECI Document. 2011b. [Internal Departmental Document, Prioritised opportunities template, used by AECI].

Internal AECI Document. 2011c. [Internal Departmental Document, Opportunities Database, used by AECI].

Internal AECI Document. 2011d. [Internal Departmental Document, Quarterly Progress Report, used by AECI].

International Energy Agency (IEA). 2015. World Energy Outlook. Available on the website at: www.iea.org/media/news/WEO_INDC_Paper_Final_WEB.PDF (Accessed 01 January 2019).

International Energy Agency (IEA). 2017. World Energy Outlook 2017; [Online] available on the web at https://www.iea.org/weo2017/ [accessed 17 Dec 2018]

Javied, T., Rackow, T. & Franke, J. 2015. *Implementing energy management system to increase energy efficiency in manufacturing companies*. 12th Global Conference on Sustainable Manufacturing. Procedia CIRP 26:156-161.

Jena, P. 2009. *A study of changing patterns of energy consumption and energy efficiency in the Indian manufacturing sector*. Leibniz University of Hannover, 1-21.

Kelly, M. 2016. *International approaches to industrial energy efficiency: A comparison of countries*. Eceee Industrial Summer Study Proceedings, September 2016, pp.91-100.

Khalaf, M.A., Labib, A.A. & ElSayed, A.E. 2011. An investigation into the relationship between the implementation of lean manufacturing and energy efficiency in industrial organizations. *Australian Journal of Basic and Applied Sciences,* 5(12):1886-1896.

Kleindorfer, P. 2010. Risk management for energy efficiency projects in developing countries. INSEAD Working Paper Series; 2017.

Lindberg, C.F., Tan, S., Yan, J. & Starfelt, F. 2015. Key performance indicators improve industrial performance. *Energy Procedia*, 75:1785-1790.

Kohler, M. 2014. Differential electricity pricing and energy efficiency in South Africa. *Energy,* 64:524-532.

Lin, B. & Chen, G. 2018. Energy efficiency and conservation in China's manufacturing industry. *Journal of Cleaner Production,* 174:492-501.

Mahapatra, K., Hallgren, R., Bischoff, L., Tugla, N., Kuai, L., Yang, Y. & Umoru, I. 2017. A behavioral change-based approach to energy efficiency in a manufacturing plant. *Energy Efficiency,* 11:1103-1116.

Martínez, C.I.P. 2010. Investments and energy efficiency in Colombian manufacturing industries. *Energy and Environment,* 21(6):545-562.

Martinez, C.I.P.2016. *Estimating and analyzing energy efficiency in German and Colombian manufacturing industries using DEA and data panel analysis. Part II: Nonenergy intensive sectors.* Energy Sources, Part B: Economics, Planning, and Policy.

Martinez, C.I.P. & Silveira, S. 2012. Energy efficiency and CO2 emissions in Swedish manufacturing industries. *Energy Efficiency,* 6:117-133.

Mathews, G.E. & Vosloo, J.C. 2015. *The benefits of energy efficiency programs-comparing Germany with South Africa.* Proceedings of the Conference on the Industrial and Commercial Use of Energy, ICUE 2015-September, 166-170.

May, G., Barletta, I., Stahl, B. & Taisch, M. 2015. Energy management in production: A novel method to develop key performance indicators for improving energy efficiency. *Applied Energy*; 149:46-61.

May, G.; Stahl, B.; Taisch, M. & Kiritsis, D. 2017. Energy management in manufacturing: From literature review to a conceptual framework. *Journal of Cleaner Production;* 167:1464-1489.

Mukherjee, K. 2008. Energy use efficiency in the Indian manufacturing sector: An interstate analysis. *Energy Policy,* 36:662–672.

Mukherjee, K. 2010. Measuring energy efficiency in the context of an emerging economy: The case of Indian manufacturing. *European Journal of Operational Research,* 201:933-941.

Modise, M. 2013. 'Overview on the National Energy Efficiency Strategy (NEES) Post 2015'. Available at: http://www.energy.gov.za/. (Accessed 30 December 2018).

National Business Initiative. 2015a. *The Private Sector Energy Efficiency Programme: Two years of focussed energy-efficiency interventions in the private sector.* Available on the website at: https://www.nbi.org.za/wp-content/uploads/2016/06/PSEE-brochure_final_LO-RES.pdf. (Accessed 30 December 2018).

National Business Initiative. 2015b. *The PSEE improving energy efficiency in commercial and industrial companies.* Available at: http://www.psee.org.za/overview.php (Accessed 30 December 2018).

NCPC-SA. 2014. Available on the website at: www.ncpc.co.za (Accessed 30 December 2018).

NCPC-SA. 2013. SAPPI Cape Kraft Case Study. Available on website on: http://ncpc.co.za/media-room-ncpc/case-studies-and-success-stories/case/case-study-sappi-cape-craft-enms (Accessed 30 December 2018).

NCPC-SA Polyoak. 2013. *Introduction and Implementation of an Energy Management System and Energy Systems Interventions*. Available on website: http://ncpc.co.za/ (Accessed 30 December 2018).

NCPC-SA AMKA Products. 2014. AMKA *Products Steam System Optimisation.* Available on website: http://ncpc.co.za/media-room-ncpc/case-studies-and-success-stories/case/case-study-amka-products-sso (Accessed 30 December 2018).

NCPC-SA SOCKIT Manufacturing. 2014. *Steam and compressed air energy systems intervention.* Available on website: http://ncpc.co.za/media-room-ncpc/case-studies-and-success-stories/case/case-study-amka-products-sso (Accessed 30 December 2018).

NCPC-SA BMW. 2016. *Case Study*. Available on website: http://ncpc.co.za/media-room-ncpc/case-studies-and-success-stories/case/case-study-amka-products-sso (Accessed 30 December 2018).

NCPC-SA Distell. 2013. *Wine and Spirit Manufacture and Bottling*. Available on website: http://ncpc.co.za/media-room-ncpc/case-studies-and-success-stories/case/case-study-amka-products-sso (Accessed 30 December 2018).

NCPC-SA ArcelorMittal. 2013. *Introduction and Implementation of an Energy Management System and Energy System Optimisation*. Available on website: http://ncpc.co.za/ (Accessed 30 December 2018).

Neelis, M., Patel, M.K., Ramirez, A. & Farla, J. 2007. Energy efficiency developments in the Dutch energy-intensive manufacturing industry, 1995-2003. *Energy Policy,* 35:6112-6131.

Ngai, E.W.T., Chau, D.C.K., Poon, J.K.L. & To, C.K.M. 2013. Energy and utility management maturity model for sustainable manufacturing process. *International Journal of Production Economics*, 146:453–464.

Onut, S. & Soner, S. 2006. Analysis of energy use and efficiency in Turkish manufacturing sector SMEs. *Energy Conversion and Management,* 48:384-394.

Parker, S. & Liddle, B. 2016. Energy efficiency in the manufacturing sector of the OECD: Analysis of price elasticities. Independent Researcher, Bethesda, MD, USA. *Energy Economics,* 58:38-45.

Parker, S. & Liddle, B. 2017. Economy-wide and manufacturing energy productivity transition paths and club convergence for OECD and non-OECD countries. *Energy Economics*, 62:338–346.

Pons, M., Bikfalvi, A., Llach, J. & Palcic, I. 2013. Exploring the impact of energy efficiency technologies on manufacturing firm performance. *Journal of Cleaner Production*, 52:134-144.

Praetorius, B. & Bleyl, J.W. 2006. Improving the institutional structures for disseminating energy efficiency in emerging nations: a case study for energy agencies in South Africa. *Energy Policy,* 34:1520-1531.

Rasmussen, J. 2015. The additional benefits of energy efficiency investments – a systematic literature review and a framework for categorisation*. Energy Efficiency*, 1–21.

Republic of South Africa. 2003. *Integrated Energy Plan for the Republic of South Africa.* Department of Minerals and Energy: Tswane.

Republic of South Africa. 2016. *Draft Post-2015 National Energy Efficiency Strategy. Department of Energy.* 1-47. Pretoria.

Rietbergen, M.G. & Blok, K. 2010. Setting SMART Targets for Industrial Energy Use and Industrial Energy. *Efficiency Journal,* 4339-4354.

Rohdin, P. & Thollander, P. 2006. Barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden. *Energy,* 31:1836-1844.

SAPPI. 2017. SAPPI Group Sustainability Report. Available on website on: https://cdn-s3.sappi.com/s3fs-public/2017-Sappi-Group-Sustainability-Report.pdf (Accessed 30 December 2018).

Schmidt, C., Li, W., Thiede, S., Kornfeld, B., Kara, S. & Herrmann, C. 2016. Implementing Key Performance Indicators for Energy Efficiency in Manufacturing. *Procedia CIRP,* 57:758–763.

Singh, R. & Lalk, J. 2016. *An investigation into the barriers to energy efficiency within medium to large manufacturing firms operating within the eThekwini municipal area. South African Journal of Industrial Engineering,* 27(3):287-302.

Solnordal, M.T. & Foss, L. 2018. Closing the energy efficiency Gap - A Systematic review of empirical articles on drivers to energy efficiency in manufacturing firms. *Energies,* 11: 518, 1-30.

Solnordal, M.T. & Thyholdt, S.B. 2017. Drivers for energy efficiency: an empirical analysis of Norwegian manufacturing firms*. Energy Procedia,* 142 2802-2808.

Solnordal, M.T. & Thyholdt, S.B. 2019. Absorptive capacity and energy efficiency in manufacturing firms – An empirical analysis in Norway. *Energy Policy,* 132:978-990.

Steinbucks, J. & Neuhoff, K. 2014. Assessing energy price induced improvements inefficiency of capital in OECD manufacturing industries. *Journal of Environmental Economics and Management,* 68:340-365.

Swilling, M. & Annecke, E. 2012. *Just transitions: explorations of sustainability in an unfair world.* UCT Press. 1-360

Tanaka, K. 2008. Assessment of energy efficiency performance measures in industry and their application for policy. *Energy Policy,* 36(8):2887-2902.

Thollander, P., Danestig, M. & Rohdin, P. 2007. Energy policies for increased industrial energy efficiency: Evaluation of a local energy programme for manufacturing SMEs. *Energy Policy,* 35:5774–5783.

Thollander, P., Backlund, S., Trianni, A. & Cagno, E. 2013. Beyond barriers - a case study on driving forces for improved energy efficiency in the foundry industries in Finland, France, Germany, Italy, Poland, Spain, and Sweden. *Applied Energy*, 111:636-643.

Times Live. 2017. South Africa amongst nations taking lead in clean Energy: World Bank. Available on website: https://www.timeslive.co.za/news/sci-tech/2017-02-15-south-africa-amongst-nations-taking-lead-in-clean-energy-world-bank/ (Accessed 3 June 2018).

Times Live. 2018. Finance Minister Tito Mboweni's 2018 medium-term budget policy statement. Sunday Times. Available at: <https://www.timeslive.co.za/sunday-times/business/2018-10-24-in-full--finance-minister-tito-mbowenis-2018-medium-term-budget-policy-statement/ (Accessed 25 October 2018).

Trianni, A. Cagno, A., Worrell, E. & Pugliese, G. 2013. Empirical investigation of energy efficiency barriers in Italian manufacturing SMEs. *Energy,* 49:444-458.

Trianni, A., Cagno, E. & Farne, S. 2016. Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small- and medium-sized enterprises. *Applied Energy,* 162:1537-1661.

Tranfield, D., Denyer, D. & Smart, P. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review*. British Journal of Management*, 14(3):207-222.

Wang, Q. & Li, R. 2014. Drivers for energy consumption: A comparative analysis of China and India. *Renewable and Sustainable Energy Reviews,* 62: 954–962

World Energy Outlook. 2018. Available at: https://www.iea.org/weo2018/. Accessed on: 21 June 2019.

Yang, M. & Yang, F. 2016. Energy-Efficiency Policies and Energy Productivity Improvements: Evidence from China's manufacturing industry. *Emerging Markets Finance and Trade*, 52: 1395-1404.

Zhao, Y., Ke, J., Ni, C.C., McNeil, M., Khann, N.Z., Zhou, N., Fridley, D. & Li, Q. 2014. A comparative study of energy consumption and efficiency of Japanese and Chinese manufacturing industry. *Energy Policy,* 70:45-56.

South Africa's petrol and electricity prices vs the world, 24 March 2019, Business Tech available at: https://businesstech.co.za/news/energy/306592/south-africas-petrol-and-electricity-prices-vs-the-world/. (Accessed: 29 June 2019).

Appendices

Appendix A: Questionnaire

Participation in Research Study undertaken by Tredeshnee Naidu, Student number: 20535147

You are asked to participate in a research study conducted by Tredeshnee Naidu, from the School of Public Leadership at Stellenbosch University. The results will contribute towards her research paper. You were selected as a possible participant in this study because you have been involved in AECI's Green Gauge Programme.
The main objective of the study is to evaluate the effectiveness of AECI's Green Gauge Resource Efficiency Programme with respect to energy efficiency.

Questionnaire to environmental practitioner or engineer involved in AECI's Green Gauge Programme

1. Do you think the Green Gauge programme was beneficial in achieving energy savings for your facility? Please expand.

2. What were the factors driving implementation of energy efficiency opportunities identified at your facility?

3. Were you able to easily motivate for capital for energy saving projects? Explain.

4. What were some of the challenges faced with AECI's Green Gauge Programme?

5. Would you support a programme similar to Green Gauge for your facility in the future? Explain.

6. Optional: Please provide a few improvement opportunities related to the Green Gauge Programme.